ENVIRONMENTAL ANALYSIS

Proposed
P-15 and P-17
Underground Uranium Mines
Jackpile-Paguate Minesite
The Anaconda Company

Laguna Tribal Lease 4
Laguna Indian Reservation
Valencia County, New Mexico

U. S. Geological Survey
Conservation Division
Branch of Mining Operations
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July 12, 1976

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I. Description of the Proposed Action

A. Introduction

The proposed action was submitted to the U. S. Geological Survey March 18, 1976, by The Anaconda Company, New Mexico Operations, Uranium Division, under the provisions of Title 25 CFR Part 177.7. It consists of a mining and reclamation plan for two underground uranium mines located within the boundaries of Laguna Tribal Uranium Mining Lease 4 which occupies approximately 2,560 acres of the Laguna Indian Reservation in Valencia County, New Mexico (Maps A and B).

The land description for Laguna Lease 4 is as follows:

Township 10 North, Range 5 West, N.M.P.M.:

Sec. 3, S½S½NW¼, SW¼ (200 acres);

Sec. 4, S½S½N½, S½ (400 acres);

Sec. 5, SE¼NW¼, Lots 1 & 2, S½NE¼,
E½SW¼, SE¼ (439.79 acres);

Sec. 8, NE¼NW¼,N½N½SE¼NW¼,NE¼, NE¼SE¼,
E½W½SE¼SE¼, E½SE¼SE¼ (280 acres);

Sec. 9, All (640 acres);

Sec. 10, NW¼, N½SW¼, N½S½SW¼ (280 acres);

Sec. 16, N½ (320 acres).

The Anaconda Company acquired the lease through negotiations with the Pueblo of Laguna, and it became effective July 30, 1963, for a term of 10 years "and as long thereafter as the minerals specified are produced in paying quantities." The original lease contained 9061,08 acres; since that time, the company has relinquished 6501.29 acres bringing the lease to its present size of 2559.79 acres.

Anaconda also holds Laguna Tribal Uranium Mining Lease 1 which lies northeast of and immediately adjacent to Lease 4. This lease was also negotiated with the Pueblo of Laguna, and it became effective May 7, 1952, for a term of 10 years "and as long thereafter as the minerals specified are produced in paying quantities." Originally, the lease contained about 800 acres, but subsequent amendments in 1954, 1956, and 1960 brought the lease to its current area of 4,988.48 acres. An agreement dated June 10, 1974, unitized the company's Laguna leases so that "exploration, development and production on any one or more of such leases shall be deemed to satisfy any and all exploration, development and production requirements on all leases between the parties."

The surface and mineral rights within Leases 1 and 4 are owned entirely by the Pueblo of Laguna.

Implementation of the proposed action would result in two separate, relatively small, underground uranium mines designated as the P-15 and P-17 Mines. They would be located in an area of about 640 acres approximately 2 miles south of the small Indian village of Paguate and about 5 miles north of the village of Laguna (Map A). The P-15 Mine would be located in Section 9, T. 10 N., R 5 W., and it would take about 7 years to develop and mine the estimated 517,644 tons of uranium ore. The P-17 Mine would be in Section 9 and 16, T. 10 N., R. 5 W., and the estimated 594,666 tons of ore would be developed and mined in about 8 years (Map B).

The proposed action was submitted March 19, 1976, to the Southern Pueblos Agency of the Bureau of Indian Affairs (BIA) in Albuquerque, New Mexico for recommendations for the protection of non-mineral resources and for the reclamation of the land surface that would be affected by the plan. The BIA, in turn, submitted the proposed action to the Laguna Tribal Council for its recommendations and approval of the plan. Appendix X of this EA contains the BIA's and the Council's comments.

No actions by other State and/or Federal agencies or authorities are pending. Prescribed postings of public notices of the proposed action resulted in no inquiries, comments or evidence of controversy.

B. P-15 Mine

The P-15 Mine workings would be located adjacent to the southernmost end of the P-10 Mine, and they would extend southward for approximately 3200 feet (Map B). A vertical, circular shaft with a finished inside diameter of 12 feet would be sunk and concrete lined by conventional methods to a depth of 625 feet (Photo A). This shaft would serve as the production shaft for hoisting ore and waste rock to the surface, and it would provide access to the mine for personnel and supplies. The shaft would be downcast to supply air to the mine workings for proper ventilation. A mining and development contractor would be engaged to sink the shaft, cut the shaft station, and to do part of the subsequent drift and raise development.

Mining of the P-15 ore bodies would be done by conventional modified room-and-pillar stoping methods with sublevel track haulage. Raises would be driven from the haulage level into the overlying ore lenses, and the ore would then be developed by small access drifts driven through and around the mineralized areas. Stoping would take place next with internal waste pillars left in place for support. Additional ground support would be provided by rock bolts, steel sets, timber sets, stulls, and/or cribbing. When two or more ore bodies are stacked, development and stoping would take place from the uppermost to the lowest ore body in descending order.

In addition to the production shaft, eleven ventilation boreholes equipped with surface fans would be needed during the life of the operation for proper ventilation of the mine. These boreholes would be drilled from the surface with 48-inch diameters and then cased with 42-inch inside diameter casing cemented in place (Photo B). The depths of the holes would range from 432 to 650 feet. Axial flow vane-type fans ranging from 25 to 100 horsepower would be used on the vent holes, and each hole would most likely be equipped with a heater to prevent freezing (Photos C and D). Each vent shaft would be capable of handling about 40,000 cubic feet of air per minute (CFM).

About 200,000 to 250,000 CFM would be required by the mine during full production. The vent holes have been tentatively located so that the haulage drifts would normally be under positive pressure and the stopes under negative pressure, but their exact locations and order of completion would be determined as mine development proceeded. Furthermore, not all of the vent holes would necessarily be equipped with fans at any given time, particularly during the later years of the mine's life. As mining proceeded and the workings were advanced beyond the effective usefulness of the holes near the production shaft, they would be abandoned as others were drilled. The upcast or downcast nature of each vent hole would also depend on mining progress. The vent shafts at the extremities of the mine would be upcast, but as mining proceeded beyond the usefulness of these shafts, new upcast vent holes would be drilled and the former shafts reduced in capacity or abandoned.

Vent hole #1 which would be located about 300 feet north of the production shaft would be equipped with a small hoist and torpedo type cage to provide a second independent exist from the mine (Photo E). This would satisfy state mining regulations and permit more than ten men to be underground at one time. In addition, a mobile crane with sufficient hoisting capacity and cable would be used at any vent shaft as an emergency hoisting unit.

Surface drilling indicates that the P-15 ore bodies contain an estimated 517,644 tons of uranium ore. According to the plan, shaft sinking would commence in mid-1976 with ore production beginning at the start of 1978. The life of the mine would be about 7 years, and about 125 persons would be employed during maximum production of 500 tons of ore per day.

Access to the mine would be provided by a road about 30 feet in width which would join paved State Highway 279 about 2 miles south of Paguate (Map B). This access road would be for normal highway vehicles only; and, from its junction with Highway 279, it would extend west for about 2800 feet where it would intersect the mine's haulage road. The haulage road would be about 50 feet wide to accommodate off-highway truck haulage units and would have a total length of approximately 8900 feet from the mine to the stockpile area. The proposed road locations have been planned to avoid as much excess cut and fill as possible. Both roads would be surfaced with waste rock material from the mining operations, and culverts would be used where the roads crossed major drainage channels. Both roads would occupy an area of about 12.14 acres.

The mine yard would occupy about 7.23 acres (700 feet long by 450 feet wide), and approximately 131,000 tons of waste rock from shaft, haulage drift, raise, and vent shaft development would be used to level the area for supply storage and ore stockpiling. At the beginning of site preparation activity, topsoil in the area would be removed and stored for use in covering the disturbed area for reclamation purposes at the end of mining operations. A combination office-change house (100x50'), a shop (80'x40'), and a hoist house (40'x40') would be the main buildings erected within the mine yard. Photos F and G show the surface facilities for the producing P-10 Mine. The facilities for the P-15 Mine would be very similar to these except that a headframe and hoist house would be required. Access to the P-10 Mine is through an inclined shaft.

Two earthen settling ponds, each measuring 6 feet deep by 200 feet long by 100 feet wide (about 1.28 acres), would be constructed about 550 feet northeast of the P-15 shaft. Each of the ponds would be lined with either an impervious clay or plastic liner to prevent seepage, and each one would be capable of handling a constant flow of about 5 gallons of water per minute (GPM). Groundwater seeping into the mine workings would be pumped through pipes from the shaft to the ponds where it would be retained to settle out the suspended particulate matter and evaporate the liquid portion. Surface runoff from the ore stockpile area within the mine yard would also be diverted by berms to these retention ponds. The particulate matter that would settle to the bottom of the ponds would be cleaned out periodically and transferred to waste or ore stockpiles depending on the U_3O_8 content of the material. Access to the ponds would be provided by existing roads.

Although it is not possible to accurately predict or estimate the actual water flow into the mine workings, it is anticipated that the inflow would be quite small. The ore bodies are located in strata that are up dip from presently operating mines, and these strata are naturally drained by surrounding ravines and canyons. The operating P-10 Mine which is approximately 0.5 miles down the regional dip from the proposed P-15 Mine is currently pumping about 183 GPM. During the mine's development period, an accurate estimate of the mine water inflow rate would be obtained. If this information indicated that additional water would be encountered, additional ponds would be constructed to accommodate the increased flow or a pipe line would be constructed to carry the additional mine water to the P-10 Mine's holding pond in the bottom of the South Paguate Pit. Some of the water in the P-10 pond is used to suppress dust on the open-pit haulage roads, the rest being retained for evaporation.

Two sewage lagoons, each measuring 100 feet long by 70 feet wide, would be constructed about 550 feet north of the shaft. These lagoons would occupy about 0.75 acres and would be of sufficient capacity to dispose of all organic wastes from the mine. They would comply with the state standards and regulations, and the plans for the lagoons would be submitted to the New Mexico Environmental Improvement Agency (EIA) for approval prior to construction. The sewage lagoons would not be associated with any other sanitation facilities, and existing roads would provide access to them.

Water for the mine and surface facilities would be provided by a well located in or near the mine yard area. The well would be completed either in sandstone units of the Brushy Basin Member or in the Westwater Canyon Member of the Jurassic Morrison Formation depending upon the quantity and quality of the water from the producing sands. The mine and support facilities would require about 30 gallons per minute from the well.

Approximately 8,600 feet of surface power lines would be required to bring electricity to the P-15 Mine's facilities and ventilation boreholes. Erection of the lines would cause virtually no surface disturbance except for the very small areas required to set the power poles in the ground. Existing roads would be used for access during construction of the lines, and the power cables would be pulled through and installed manually. The lines would be removed at the end of mining operations.

Boring of the eleven ventilation shafts would require about 1.89 acres. Each site would be a minimum of 50 feet by 150 feet in order to set up the drill rig and supporting equipment (Photo B). The existing network of roads on Black Mesa would provide access to the sites for construction.

Throughout the life of the mine, the mine yard, vent shaft areas, sewage lagoons, and the settling ponds would be fenced.

C. P-17 Mine

The P-17 Mine (shaft) would be about 4,000 feet southeast of the P-15 shaft, and the sequences of events and the mining methods would be essentially the same as those for the P-15 Mine. A vertical, circular shaft would be sunk by conventional methods to a depth of 575 feet to gain access to the ore bodies (Photo H). The 12-foot diameter shaft would be concrete lined over its entire depth. The shaft would be used for hoisting ore and waste, personnel, and supplies, and it would be downcast to provide air for mine ventilation. A mining and development contractor would sink the shaft and perform part of the primary mine development.

The P-17 ore bodies would also be mined using conventional modified room-and-pillar stoping methods with sublevel track haulage. Raises would be driven from the haulage sublevel directly into the ore and the stopes subsequently developed by driving drifts through and around the perimeter of the ore bodies. Waste pillars would again be left for ground support supplemented by rock bolts, steel sets, stulls, timber sets, and/or cribbing.

Sixteen ventilation shafts equipped with surface fans would be required during the mine's life for proper ventilation of the mine workings. These vent holes would be identical in construction to those for the P-15 Mine except their depths would range from 261 to 625 feet. Each hole would have a maximum capacity of 40,000 CFM.

The P-17 Mine would also require 200,000 to 250,000 CFM of ventilating air at maximum production. As in the case of the P-15 Mine, the vent shafts for the P-17 Mine have been tentatively located so that the haulage drifts would normally be under positive pressure and the stopes under negative pressure; however, their exact locations and order of completion could vary slightly as determined by mine development. Also, not all of the shafts would necessarily be equipped with fans at any given time, especially during the later years of the mine's life. As at the P-15 Mine, the use, capacity, and upcast or downcast nature of the vent holes would be determined by mining progress.

Vent hole #1, located about 150 feet southeast of the main shaft, would be equipped with a small hoist and torpedo type cage to provide a second independent exist from the mine (Photo E). This would comply with state regulations and allow more than ten men to be underground at one time. A mobile crane with ample cable and hoisting capacity would also be used at any vent shaft as an emergency hoisting unit.

Surface exploration drilling indicates that the P-17 ore bodies contain an estimated 594,666 tons of uranium ore. Shaft sinking would commence in January of 1977 with ore production beginning in the middle of 1978. The mine would have a life of about 8 years, and about 150 persons would be employed during maximum production of 700 tons of ore per day.

A 50-foot wide ore haulage road would be constructed from the P-15 to the P-17 for access. This road would start at its junction with the P-15 haulage road at the entrance to the P-15 mine yard and proceed southeast for about 3600 feet to the P-17 mine yard (Map B). Approximately 650 feet southeast of the P-15 mine yard, a 30-foot wide access road would branch off the ore haulage road to travel 1100 feet south to the explosives storage area. These roads would be surfaced with waste rock material from the mining operations, and culverts would be used where the roads cross major drainage channels. The roads would occupy about 4.89 acres, and their proposed locations have been planned to avoid as much excess cut and fill as possible.

The P-17 mine yard would occupy about 5.51 acres (600 feet long by 400 feet wide), and approximately 141,000 tons of waste rock from shaft, haulage drift, raise, and vent shaft development would be used to level the area. At the start of site preparation, topsoil would be removed and stored for use in covering the disturbed area for reclamation at the end of mining operations. An office-change house (100'x50'), a shop (80'x50'), and a hoist house (40'x40') would be the main buildings erected within the mine yard (Photos F and G).

The explosives storage area would be located about 1800 feet south of the P-15 shaft and about 2100 feet northwest of the P-17 shaft. Explosive storage regulations require a relatively large area to be cleared of all flammable material. The area required by such regulations is about 2.58 acres, and the area's proposed location complies with the latest available "American Table of Distances for Storage of Explosives." Two small buildings, a detonator magazine (20'x20') and a dynamite magazine (50'x20'), would be erected within the area.

Two earthen settling ponds would be constructed about 550 feet southwest of P-17 shaft. These ponds would be identical in size, construction, and capacity to those at the P-15 Mine, and they would occupy about 1.29 acres. Groundwater seeping into the mine workings would be piped from the shaft to these ponds, and surface runoff from the ore stockpile area would also be diverted to them for settling of suspended solids and subsequent evaporation of the liquid portion. Collected sediments in the bottom of the ponds would be cleaned out periodically and transferred to waste or ore stockpiles depending on the U_3O_8 content of the material. Access to the ponds would be provided by existing roads.

As for the P-15 Mine, it is not possible to accurately predict the actual amount of water flow into the mine. However, the P-17 Mine would be about 4,000 feet up dip of the P-15 Mine so it seems reasonable to anticipate less inflow into the P-17 Mine. During mine development, an accurate estimate of the inflow rate would be obtained. If a larger inflow rate was indicated, additional pond area would be constructed or a pipe line would be built to carry the excess water to the P-10 holding pond in the South Paguage Pit.

About 350 feet northeast of the shaft, two sewage lagoons would be built. Each lagoon would be about 100 feet long by 70 feet wide, and they would be of sufficient capacity to dispose of all organic wastes from the mine. Both lagoons would occupy about 0.72 acres. They would be built in accordance with state standards and regulations, and plans would be submitted to the New Mexico EIA for approval prior to construction. The lagoons would not be associated with any other sanitation facilities, and existing roads would provide access to them.

Water for the mine and surface facilities would be provided by a well located in or near the mine yard area. The well would be completed either in sandstone units of the Brushy Basin Member or in the Westwater Canyon Member of the Jurassic Morrison Formation depending upon the quantity and quality of the water from the producing sands. The mine and support facilities would require about 30 gallons per minute from the well.

Approximately 10,900 feet of surface power lines would be required to bring electricity to the P-17 Mine's facilities and ventilation boreholes. Erection of these lines would cause virtually no surface disturbance except for the very small areas needed to set the power poles in the gound. Existing roads would be used for access during construction of the lines and the power cables would be pulled through and installed manually. The lines would be removed at the end of the mining operations.

Each of the sixteen ventilation shafts required by the mining operations would need a minimum site area of 7500 square feet (150 feet long by 50 feet wide) to set up the drill rig and supporting equipment (Photo B). This would result in surface disturbance to about 2.76 acres total. Existing exploration roads would provide access to the sites.

Throughout the life of the mine, the mine yard, vent shaft areas, sewage lagoons, and the settling ponds would be fenced.

D. Ore Processing

The ore produced at each mine would be hoisted to the surface through the production shafts to be stockpiled within the mine yards. Only one or, at most, two days production would be located in the yards at any given time as it is anticipated that the ore would be trucked daily to existing stockpile areas about 1 mile east of the P-10 Mine. At the approved P-10 stockpile locations, the ore would be loaded into rail cars and then transported by the Atchison, Topeka, and Santa Fe Railway (AT&SF) to the company's operating Bluewater Mill which is about 50 miles to the west near Grants, New Mexico.

The Bluewater Mill currently has the capacity to process 3,500 tons of ore per day. The mill utilizes an acid-leach hydrometallurgical process to recover and concentrate the ore's natural uranium into a precipitated and dried product known commonly as yellowcake (U_3O_8). The ore from the P-15 and P-17 Mines would be used as feed material for this process with the resultant yellowcake being sold to a utility company for further processing and ultimate use in nuclear powered electric generating plants.

E. Reclamation

The reclamation programs for the P-15 and P-17 Mines would be essentially the same. Upon the conclusion of operations at each mine, all mine openings would be sealed in accordance with regulations in effect at that time, and reclamation operations would commence. It is anticipated that it would take approximately 2 months at each mine to complete the reclamation work.

The haulage and access roads and ventilation shaft areas would be graded, scarified, limed if necessary, and then seeded. The mine yard areas would be covered with the topsoil that would be removed and stockpiled at the start of surface operations with seeding to follow.

Sediments that would have collected in the settling ponds would be removed and transferred to waste or ore stockpiles depending on the U_3O_8 content of the material. The ponds would then be backfilled, graded, and seeded. The sewage lagoons would be backfilled, graded, and seeded. According to state law it would be permissable to bury the residual waste material in the lagoons.

According to Agreement 16 of the involved Lease 4, all reclamation work would be to the satisfaction of the Superintendent of the Southern Pueblos Agency of the BIA. The disposition of the permanent structures erected for both operations would be carried out according to Agreement 3 of said lease.

F. Related Actions

Two proposed actions relating to New Mexico's uranium industry are currently pending before the Conservation Division of the U. S. Geological Survey. Plans for the Kerr-McGee Corporation's Church Rock II and III Mines were submitted April 14 and August 28, 1975, respectively. These proposals involve underground uranium mining operations on Navajo Tribal Uranium Leases 14-20-0603-9986, -9987,-9988, and -9992 which are located in Township 17 North, Range 16 West, N.M.P.M., on the Navajo Indian Reservation, McKinley County, New Mexico. Environmental analyses have been completed for each of the plans, and approval of the plans by the Navajo Nation and the BIA was granted in June 1976.

The Kerr-McGee Corporation's supplemental mining plan for proposed changes in their operating Church Rock I Mine (underground uranium) was approved June 22, 1976, after concurrence was given by the Navajo Nation and the BIA. This plan was submitted July 28, 1975, as a supplement to the original mining plan that was approved June 11, 1971. The plan involves Navajo Tribal Uranium Leases 14-20-0603-9987, -9988, and -9990 in Township 17 North, Ranges 15 and 16 West, N.M.P.M., on the Navajo Indian Reservation, McKinley County, New Mexico.

Another related action, Gulf Mineral Resources Company's mining and reclamation plan for the Mariano Lake Mine, was recently processed and approved by the Conservation Division. This plan was submitted June 26, 1975, and provides for a small underground uranium mine on Navajo Allotted Uranium Leases 14-20-0603-1345, -1349, and -1351 located in Township 15 North, Range 14 West, N.M.P.M., McKinley County, New Mexico. The environmental analysis for the proposal was completed May 10, 1976, with approval coming June 4, 1976.

According to officials for The Anaconda Company, the company is currently in the process of composing a comprehensive mining and reclamation plan that would cover all of its open-pit and underground uranium mining operations at the Jackpile-Paguate Minesite. This plan will be submitted to the Conservation Division upon completion.

II. Environmental Considerations of the Proposed Action

A. Geology

1. Physiography

The Anaconda Company's Jackpile-Paguate Minesite lies almost in the center of the Laguna Uranium Mining District which is an area of about 535 square miles on the east side of the Colorado Plateaus physiographic province (Map C) (Moench and Schlee, 1967, p. 3). Structurally, this area is in the southeastern part of the San Juan Basin, a broad topographic depression characterized by broad open valleys and mesas and local deeply incised drainage features. The Mount Taylor volcanic field is located to the north and west of the area (Dinwiddie, 1963, p. 217).

The Laguna District is located in mesa country that is typical of much of the Colorado Plateaus province. Mesa Chivato, the largest and highest mesa, rises to an altitude of 8,000 feet above sea level on the northwest side of the district with its flat lava top covering about 400 square miles. Mesa Gigante rises to an altitude of more than 6,500 feet on the southeastern side, and the similar but much smaller Mesa Prieta is located on the northeastern side about 14 miles east of Mesa Chivato (Map A). Between these prominent landmarks are smaller mesas and benches. The northeastern part of the district is characterized by low mesa and bench topography, and in this area as well as farther south, the land surface is pierced by several volcanic necks that rise abruptly to as much as 1,000 feet above the surrounding landscape (Moench and Schlee, 1967, pp. 3-4). From the southern part of Mesa Chivato, the roughly conical Mount Taylor, a large inactive volcano, rises more than 11,300 feet above sea level and more than 5,000 feet above the valley of the Rio San Jose to the south (Hunt, 1936, p. 36).

The perennial Rio San Jose is the main drainage in the Laguna District. It drops from an elevation of about 5,900 to less than 5,600 feet from west to east, and it is entrenched 20 feet or more over most of its length. A few miles southeast of the district, it joins the Rio Puerco, a tributary of the Rio Grande (Moench and Schlee, 1967, p. 4) which flows continuously only during the wet season. The Rio Puerco drains the west flank of the Nacimiento Mountains forming the east boundary of the district (Hunt, 1937, p. 37).

Several arroyos join the Rio San Jose from the north and south, but ordinarily most of them flow only after summer thunderstorms. The largest of these arroyos are the perennial Rio Paguate and the intermittent Arroyo Conchas which drain the area to the north of the Rio San Jose and the Arroyo Colorado which drains the broad valley to the south. The Arroyo Salado drains the northeast corner of the district and joins the Rio Puerco to the east (Moench and Schlee, 1967, p. 4). All the main streams and tributaries are entrenched into arroyos cut in the alluvial fill of the valleys. These arroyos carry very large quantities of water immediately after heavy precipitation, and occassionally the waters rise over the banks and spread out as sheet floods (Hunt, 1937, p. 37).

The proposed mines would be located on the steeply sloping northeast flank of Black Rim Mesa (Maps B and D) where elevations range from about 6900 to 6000 feet above sea level (Photos A, H, I, J, K). The surface is cut by several northeast trending dry washes that channel surface runoff toward the Rio Paguate.

2. Stratigraphy

The San Juan Basin is characterized by a sedimentary fill of marine and continental rocks several thousand feet thick and from Paleozoic to Quaternary in age. These sedimentary beds dip gently from the basin margins toward the center, and intrusive igneous rocks of Tertiary and Quaternary ages occur locally around the basin margins. The southern part of the Colorado Plateaus province, the Datil volcanic field (Map C), is characterized by an extensive covering of lavas and associated continental sedimentary rocks that total several thousands of feet in thickness (Hilpert, 1969, p. 9). Table I in Appendix II shows the regional stratigraphy as modified from Hilpert's compilation (1969) with the representative thicknesses of the stratigraphic units (NMEI, 1975, p. 159).

The Jackpile-Paguate Mine area is located in the southeastern part of the San Juan Basin, east of the Mount Taylor volcanic field. Rocks ranging in age from Late Triassic to Recent crop out in or near the area, and the regional dip of the beds is northward to northwestward at about 2 degrees. Minor faults and folds vary the dips locally (Dinwiddie, 1963, p. 217). Columns 2 and 3 in Appendix II show the stratigraphy in the areas of the P-15 and P-17 mines respectively according to The Anaconda Company.

The primary host for uranium deposits in northwestern New Mexico is the Morrison Formation of Late Jurassic age. The Morrison is 400 to 800 feet thick and generally consists of mudstone (gray, maroon, buff), vari-colored claystone, and medium-to coarse-grained sandstone (gray to reddish-brown). The sandstone is arkosic and locally conglomeratic and locally contains concentrations of carbonaceous materials. The Salt Wash, Recapture, Westwater Canyon, and the Brushy Basin Members make up the Morrison Formation from base to top, but the Salt Wash Member occurs only in northwestern San Juan County (Hilpert, 1969, p. 19).

In the Laguna District, the Morrison Formation is composed mostly of a relatively thick Brushy Basin Member and markedly thinner Westwater Canyon and Recapture Members. It attains its maximum thickness of about 600 feet in the central part of the district from where it thins laterally. Southward it is beveled under the pre-Dakota erosion surface, and it is absent in the southern part of the district (Hilpert, 1969, p. 71-72).

The Recapture Member in the district ranges from 0 to about 100 feet in thickness with a probable average of about 25 feet. It is composed of alternating grayish-red and greenish-gray mudstone, siltstone, sandstone, and a few thin beds of limestone. The overlying Westwater Canyon Member ranges in thickness from 0 to more than 100 feet with an average of about 50 feet. It is thickest in the northern part of the district from where it thins southward, and locally it grades into the Recapture. It consists of grayish-yellow to very pale orange, fine-to-coarse-grained, friable sandstone (Hilpert, 1969, p. 71-72).

The Brushy Basin Member overlies the Westwater Canyon and makes up most of the Morrison Formation. From the central part of the district where it is more than 300 feet thick, it thins laterally most markedly southward and is cut out in the southern part of the district under the pre-Dakota erosion surface. It is composed of grayish-green bentonitic mudstone and some sparse thin beds of clay-rich sandstone. In the lower part it contains sandstone lenses similar to the Westwater Canyon which are generally less than 20 feet thick but locally as much as 85 feet thick. In the central part of the district, the Brushy Basin contains, in its upper part, the Jackpile sandstone which is the main ore-bearing unit (Hilpert, 1969, p. 71-72).

The Jackpile sandstone contains nearly all the known deposits in the Brushy Basin Member, and all the principal deposits in the Morrison Formation, in the district. It is a tabular body about 15 miles wide by 35 miles long extending from the vicinity of Laguna to the vicinity of Mesa Prieta. It has a maximum thickness of about 200 feet a few miles north of Laguna from where it tapers to its margins and, to the northeast, splits into two fingers. The Jackpile consists of a yellowish-gray to white, friable, fine-to medium-grained, fluvial sandstone that generally grades from coarser-grained subarkosic material at the base to finer material at the top (Hilpert, 1969, p. 71-72).

3. Structure

The Laguna District is located mainly on the east limb of the McCarty's syncline which dips gently northwestward into the San Juan Basin (Map E). On the east side of the district the beds are downdropped along the north-trending, faulted Ignacio Monocline into the Rio Grande trough, and the volcanic rocks of Mount Taylor cover the western side of the district. Numerous volcanic centers, flows, dikes, and sills are located throughout the district and mark the northern part of the Datil volcanic field (Hilpert, 1969, p. 72).

Three periods of tectonic activity are generally recognized. Jurassic deformation resulted in two sets of low amplitude folds, one trending east to northeast and one trending north-northwest. This folding was accompanied by slumping and internal faulting of unconsolidated clastic sediments and by the formation of peculiar cylindrical subsidence structures or sandstone pipes. The folding also influenced sedimentation. Late Cretaceous to middle Tertiary deformation caused the tilting of the beds to the northwest.

The third period of activity occurred from middle to late Tertiary time and possibly extended into Quaternary time. This period marked the subsidence and sedimentation of the Rio Grande trough and produced the north-trending normal faults, the faulted monocline along the west border of the trough, and the joints in the sedimentary rocks. The fracturing was accompanied by the emplacement of numerous dikes and sills.(Hilpert, 1969, p. 72).

There are no recognizable geologic structures in the proposed mining area. The regional dip of all the involved sediments, Jurassic and Cretaceous, is very shallow, about 2 degrees to the northwest. A small vertical diabase sill which has a maximum thickness of 2 feet and a north-northeast trend has been mapped and may extend into the area, but the extensive colluvium cover in the area (up to 100 feet thick) effectively hides most features. Generally, there is very little geological disturbance in the area (The Anaconda Company, 1976).

4. Nature of Deposit

In the Laguna District, the largest uranium deposits are in the Jack-pile sandstone unit of the Brushy Basin Member. The deposits may be composed of one or more semitabular ore layers that range from almost equidimensional to strongly elongate in plan view. The layers are figuratively suspended within the host sandstone (Moench, 1963, p. 159), and they range in thickness from only a few inches to as much as 20 feet and occur in multiple units that are as much as 50 feet thick. The deposits' lateral dimensions range from a few feet to several thousand feet (Hilpert, 1969, p.74). The principal ore minerals of the relatively unoxidized parts of deposits are coffinite and uraninite which are intimately mixed with carbonaceous matter (Moench, 1963, p. 159).

The P-15 ore deposits are vertically distributed from the base to the top of the Jackpile sandstone at depths ranging from 470 to 650 feet. They range from 3,000 to 3,600 feet in length, from 400 to 1,400 feet in width, and from about 6 to 65 feet in thickness. The ore has an average thickness of about 15 feet. In areas where the ore bodies are stacked, the separation between them ranges from 10 to 38 feet with an approximate average of 20 feet. The P-15 ore bodies contain 517,644 tons of ore with an average grade of 0.23% U_3O_8(The Anaconda Company, 1976).

The P-17 ore deposits, however, are located in the upper two-thirds of the Jackpile sandstone at depths of about 260 to 590 feet. Here the ore bodies vary from 4,000 to 5,000 feet in length, from 200 to 1,600 feet in width, and from 6 to 35 feet in thickness. Average thickness of the ore is about 10 feet. Stacked ore bodies are separated from 10 to 33 feet with an average separation of about 20 feet. The P-17 ore bodies contain 594,666 tons of ore with an average grade of 0.23% U_3O_8 (The Anaconda Company, 1976).

5. Geologic Hazards

There are no known potentially serious geological hazards in the proposed mine area. The colluvium in the area appears to be well stabilized with no evidence of any recent significant slippage (The Anaconda Company, 1976).

Based on available data, the seismic risk for the project area seems low. An earthquake with a magnitude of 5 is possible in the Grants area about 30 airline miles to the west, but it would probably have a negligible effect on the project area (NMEI, 1975, p.174) (See Figure 1 and Tables 1 and 2 in Appendix III). The Rio Grande rift, a prominent chain of structural depressions that extends southward from south-central Colorado through New Mexico, is about 35 miles minimum southeast of the proposed project area. Investigations have concluded that the portion of this structure extending from Albuquerque to Socorro has the highest seismic risk, and it is estimated that the largest shock along this structure in a 100 year period would have a magnitude of 6. A magnitude 6 shock at a distance of 35 miles would probably not have a significant effect on the project area (NMEI, 1974, p.91)(See Figure 2 and Tables 3 and 4 in Appendix III).

Subsidence of the strata overlying the underground mine workings would not be excessive, if any at all, depending on certain combinations of ore depth and thickness, mining extraction, and strength of the overlying strata. After the extraction of smaller deposits in most uranium mines in the districts, caving over the mined out areas stops when the increased volume of the caved rock fills the void. In addition, caving of the less competent sandstone frequently ceases upon reaching a stronger layer of indurated shale within a vertical distance of less than 30 feet.

It would be possible, however, that over the thicker ore bodies or over stacked ore bodies with minimum vertical separation, the subsidence of overlying strata could be significant enough to result in some surface expression. This would probably be only a gentle depression in the surface over the underground workings, and it would not be considered necessary to have the company establish and monitor survey grid systems over the mine workings in order to detect surface subsidence during pillar removal. The closest permanent structure that could possibly be affected by surface subsidence is State Highway 279 which, at its closest point, comes within about 500 feet of two small ore pods at the southeast end of the P-17 Mine (Map B). Considering the location and size of the ore pods, any significant adverse effect on the highway is very improbable.

6. Other Mineral and Non-Mineral Resources

There are no other known mineral or non-mineral resources in the proposed mining area (The Anaconda Company, 1976).

7. Soils

The main soil type in the proposed mining area is probably a shallow, fine textured, slowly premeable, and moderately eroded soil that is developed from basic igneous (basalt) rock. It occurs on moderately steep to steep slopes (12-55%)(The Anaconda Company, 1976). See Appendix IV for a description of the soils in the area.

B. Atmosphere

1. Meteorology

The climate of most of the Laguna District is semiarid. During the summers, the days are generally hot, but the dry atmosphere and almost continual breeze prevent the high temperatures from being unpleasant. The summer nights are invariably cool. The winters are moderately cold with freezing temperatures prevailing during the winter nights. Generally, the winter days are comparatively warm and pleasant (Hunt, 1937, p.37). Day-night temperature differences are much greater in New Mexico than they are in humid areas with most weather stations showing an average diurnal variation of from 30° to 40°F (NMEI, 1974, p.38). Mean annual temperatures for New Mexico stations decrease about 5°F for every 1000 feet of elevation increase (NMEI, 1974, p.40).

The mean yearly temperature for the Jackpile-Paguate area is about

$53^{\circ}F$ (Mudgett, P-10, 1975, p.5). Based on 26 years of records for San Fidel which is about 11 miles west of Laguna, freezing temperatures ($32^{\circ}F$ and below) do not occur during May to October (NMEI, 1974, p.40). In 1975, the maximum and minimum temperatures at Laguna were $95^{\circ}F$ and $-4^{\circ}F$ respectively (White, 1976, oral communication).

The annual precipitation in the Jackpile-Paguate area ranges from 4 to 18 inches (Mudgett, P-10, 1975, p.4) with an average of just under 10 inches (Gregg, 1976, oral communication)(See Figure 1, Appendix V). Showers usually occur in May with harder, downpour type rains in the middle summer months (July-August) and early fall being common (The Anaconda Company, 1973, p.8). A steep precipitation gradient exists in the area as Mount Taylor receives about 30 inches of annual rainfall (Gregg, 1976, oral communication). Table I in Appendix V shows the mean precipitation (inches) for stations in the Mount Taylor area.

Central New Mexico receives about 75% of the available winter sunshine and about 80% of the possible summer sunshine. The annual average for Albuquerque is 77%. Similar figures should apply to the proposed mining area, but the amount of sunshine is decreased on the slopes of Mount Taylor by cumulus cloud build-up during the summer months (NMEI, 1974, p.40-41).

Relative humidity in New Mexico is generally low. It remains below 20% much of the time, and readings to 4% have been recorded. The large diurnal variations in temperature cause a large difference in maximum and minimum relative humidities (NMEI, 1974, p. 41).

There are no air-circulation data for the proposed mining area, but a 4-year summary of the winds at the Langmuir Laboratory about 17 miles southwest of Socorro (MapA)(elevation 10,630 feet MSL) may be useful for some purposes and is presented in Table 2 of Appendix V. It should be noted that air circulation patterns in northwestern New Mexico are governed by the local topography and the daily surface heating regime (NMEI, 1974, p. 41-45).

Severe weather occurrences are uncommon in the Jackpile-Paguate area although flash floods and severe water run-offs which result in considerable erosion are usual experiences in the July-August period when there is significant precipitation. Summer thunderstorms are occassionally accompanied by high winds and small hail (1/2-inch diameter or smaller), but large hail (larger than 3/4-inch diameter) is infrequent. Heavy snows (defined by the National Weather Service as 4 inches in 12 hours or 6 inches in 24 hours at lower elevations) may occur six to twelve times per year. Tornadoes in the area would be rare but not impossible (White, 1976, oral communication).

The proposed mining operations should have no effects on the meteorological conditions in the area, nor vice versa.

2. Air Quality

Particulate data for the Paguate area collected by the New Mexico EIA in 1975 indicate an annual geometric mean of 36.8 ug/m^3 for total suspended particulate matter. This is well below the maximum allowable concentration of 60 ug/m^3 under the EIA standards and 75 ug/m^3 under Federal standards (see Appendix VI for air quality regulations and data)(Rinaldi, 1976, written communication).

The proposed mining operations should have no significant adverse effects on the air quality in the area. However, a certain amount of dust would be created by the site preparation and road construction phases of the initial surface operations, by vehicular traffic on the access and haulage roads, and by reclamation operations. This dust would be only temporary, and problems could be avoided or minimized by applying adequate amounts of water to excessively dusty areas and roads.

Ore and waste rock stockpiles should not be significant sources of dust due to the large size of the smallest run-of-mine particles and the natural dampness of the material. High winds could cause a small amount of airborne dust, but most of it should settle within a short distance because of the farily heavy particle weight. Furthermore, the ore stockpiles would be quite small (1 or 2 days production maximum at each mine) as discussed in Section I.D., and the waste rock would be used to level the mine yards and would therefore be compacted to a certain degree. The loading and unloading of ore and waste material should not create any appreciable amount of dust.

Air pollution from the exhaust gases of surface equipment (loaders, bulldozers, haulage trucks, etc.) should be insignificant due to the small amount of equipment required and the use of appropriate pollution control devices.

Dust problems in the mines themselves could be controlled with the effective use of water and should have no effect on the surface atmosphere. Contamination of the mines' atmospheres by fumes from the detonation of explosives, radon gas from radium disintegration, and exhaust gases from approved diesel equipment would be maintained within acceptable limits by the mines' ventilation systems. Frequent monitoring by authorized mine personnel, Mining Enforcement and Safety Administration (MESA) inspectors, and the New Mexico State Mine Inspector would assure compliance with the applicable regulatory standards and would provide the basis for any required changes in the ventilation systems.

The contaminated mine air exhausted through the various ventilation shafts (heated air and some fine particulates) would be rapidly dissipated in the ambient surface atmosphere without adverse environmental effects. The 1971 and 1972 analyses of large ambient surface air samples by the Kerr-McGee Corporation at its uranium mines in the Ambrosia Lake district indicated no radiological contamination over the natural background count (0.15 working levels concentration) within a 150-foot radius of the bore-hole exhaust vent and a very low level of concentration at a distance of 25 feet. Similar results from parallel testing during the same time period were obtained by Edward P. Kaufman, Program Manager, Radiation Protection, New Mexico EIA (Cleveland, 1975, oral communication).

The evaporation of the water retained in the settling ponds and sewage lagoons could create a local high moisture anomaly in the air. This should not have a significant adverse effect on the environment but could, in fact, be beneficial to the local vegetation, There should be no problems with odors from the sewage lagoons due to their remote locations. Chemical treatment of the lagoon water could reduce any odor problem to an acceptable level.

The Anaconda Company has established a high volume air sampling station and currently monitors ambient air concentrations on a continuous basis. According to the company, the particulate levels have been well below the regulatory standards. The company plans to expand the program by establishing meteorology monitoring stations and by locating additional air sampling stations at strategic locations (The Anaconda Company, 1973, p.10).

3. Noise

Noise created by the proposed operations should not be a significant problem since there are no residences in, or in close proximity to, the area. The majority of the operations that would create noise would be conducted underground and would not affect the surface. Underground noise would be maintained within acceptable limits as prescribed by MESA and the New Mexico State Mine Inspector by the use of recommended muffling devices on mining equipment and by the use of hearing protection equipment by mine personnel.

The major sources of noise on the surface would be the loading and haulage equipment and the fans on the ventilation boreholes, neither of which should create a significant adverse effect. Noise from the small amount of loading and haulage equipment would be intermittent and not all of the vent holes would be equipped with fans at one time as discussed in Sections I.B. and I.C.

C. Hydrology

1. Surface Water

The main stream in the Laguna District is the perennial Rio San Jose (Map F) which is entrenched 20 feet or more over most of its length. It drops drom an altitude of about 5,900 feet to less than 5,600 feet from west to east and joins the Rio Puerco, a tributary of the Rio Grande, a few miles southeast of the district. The Rio Puerco drains the west flank of the Nacimiento Mountains but flows continuously only during the wet season (Moench and Schlee, 1967, p. 4).

The Rio San Jose is joined by several arroyos from the north and south, but the majority of these flow only after heavy precipitation. The largest such arroyos are the perennial Rio Paguate and the intermittent Arroyo

Conchas which drain the area to the north and the Arroyo Colorado which drains the broad valley to the south. All the main streams and tributaries are entrenched into arroyos cut in the alluvial fill of the valleys. The arroyos carry large quantities of water immediately after heavy precipitation and occassionally the waters rise over the banks and spread out as sheet floods (Hunt, 1937, p. 4).

In the mining lease area, the main streams are the Rio Paguate and Rio Moquino. These so-called perennial streams are sustained by springs that issue from mesas northwest of Paguate (Dinwiddie, 1963, p. 218), and they join in the Jackpile-Paguate mine area to form the Rio Paguate which flows into the Paguate Reservoir and hence into the Rio San Jose. The steeply sloping surface of the proposed mine area is cut by several northeast trending dry arroyos that channel surface runoff toward the Rio Paguate during heavy precipitation.

The main bodies of ponded water in the area are the Paguate Reservoir, the New Laguna Reservoir and a small unnamed reservoir in the village of Paguate (Map F). The Paguate Reservoir is about 2 to 3 miles southeast of the proposed mines and retains the flow of the Rio Paguate about one-half mile northeast of its intersection with the Rio San Jose. The New Laguna Reservoir is located on the Rio San Jose about 5 miles southwest of the proposed mines. The small reservoir in Paguate retains the flow of some small streams flowing from mesas to the northwest. There are numerous small, natural or man-made water catchments outside the proposed mining area, but these probably hold water only intermittently due to evaporation and seepage.

At the present time, no major use is made of the surface waters in the area. At some time in the past, the water in Paguate Reservoir was used for irrigation purposes, but this reservoir, and the New Laguna Reservoir, are currently nonfunctioning due to sediment filling.

The proposed mining operations should have little effect on the surface waters in the area due to the absence of any major sources. Anaconda would not impound or restrict any surface water although the ore storage areas in each mine yard would be surrounded by a berm to divert surface runoff. The sewage lagoons and settling ponds would not be located in any drainageways, and the settling ponds would be lined to prevent seepage.

2. Ground Water

The principal aquifers in the Jackpile-Paguate minesite area are the alluvium along the Rio Paguate, the Tres Hermanos Sandstone Member of the Mancos Shale in the western part of the area, and the sandstone beds of the Brushy Basin and Westwater Canyon Members of the Morrison Formation throughout the area (See Table 1, Appendix II)(Dinwiddie, 1963, p. 217).

Quaternary alluvium is exposed along the Rio Paguate and the tributary Rio Moquino. Although the alluvium along the Rio Moquino and the lower part of the Rio Paguate is not used as an aquifer because of the water's high dissolved solids content, the water in the alluvium along the upper part of the Rio Paguate is potable. Wells drilled west of Paguate to test the quality and quantity of this water showed that the water was suitable for domestic use and that yields of 10 to 35 gallons per minute (GPM) could be sustained. In one well, water in the lower part of the alluvium was under artesian pressure and flowed at a rate of 13 GPM (Dinwiddie, 1963, p. 218).

The sandstones in the Tres Hermanos Sandstone Member are the only units of the Mancos Shale that yield potable water, generally yielding from 5 to 20 GPM. Although larger yields have been reported, yields greater than

20 GPM would not be expected in the area (Dinwiddie, 1963, p. 217-218).

The Westwater Canyon Member of the Morrison Formation yields a small amount of potable water, between 8 to 10 GPM, to a few wells in the area. The sandstone beds of the Brushy Basin Member reportedly yield as much as 20 GPM of water east of the area, but this water has a rather high dissolved solids content. The Jackpile unit of the Brushy Basin is not considered to be a good aquifer although it reportedly yields from 8 to 10 GPM of water to one well in the area (Dinwiddie, 1963, p. 217).

The Quaternary alluvium aquifer is recharged by runoff which infiltrates to the west and north. The Brushy Basin and Westwater Canyon aquifers crop out in the valleys and the Tres Hermanos aquifers crop out extensively in the area; recharge of these aquifers is probably limited to precipitation on and runoff over the outcrops (Dinwiddie, 1963, p. 217-218). It is doubtful that there is significant communication between aquifers, and there are no known natural discharges for the aquifers in the area.

There are numerous wells in the Jackpile-Paguate area which supply water for domestic and industrial use. The Paguate municipal water supply is a flowing artesian well completed in the alluvium along the Rio Paguate at a depth of about 75 feet. Three other wells in the area, believed to be former uranium exploration drill holes equipped as water wells, are the property of The Anaconda Company and are used to supply potable water as well as water for equipment washing, etc. (Map G)(EPA, 1975, p. 57-58). One of these wells supplies domestic water for the Jackpile Mine offices and the mine housing area from the Jackpile sandstone at a rate of about 35 GPM. The P-10 Mine well is completed in the Brushy Basin Member to a depth of 465 feet and yields about 35 GPM for the mine's surface and underground uses (Mudgett, P-10, 1975, p. 10-11). Map G shows the locations of several wells in the Jackpile-Paguate minesite, but only two or three of the wells shown are still productive.

Water for the proposed mines would be supplied by a well in or near the mine yard at each shaft location as discussed in Sections I.B. and I.C. These wells would be completed in sandstone units of either the Brushy Basin Member or the Westwater Canyon Member of the Morrison Formation depending on the quantity and quality of the water from the producing sands. Each mine would require about 30 GPM from each well.

The proposed mining operations would have only minor impacts on ground water availability in the Jackpile-Paguate area as acknowledged by the Water Resources Division's hydrologist in his memorandum report (Appendix VII). The P-15 and P-17 ore bodies are located up the dip slope from the operating P-10 Mine, and would, therefore, probably be at least partially within the cone of depression created by this pressure sink. Furthermore, the ore bodies/ are located in strata that are naturally drained by surrounding ravines and canyons, and the Jackpile Sandstone which receives very little recharge crops out close to the proposed mines. According to the hydrologist's memorandum report, "In this area mining will be done at or just below the water table, so yields from the relatively impermeable material will be low and drawdown will be small."

Although the amount of water that would be encountered in each mine is expected to be small, the hydrologist's report expressed concern about the adequacy of the mines' settling ponds. Should the mine water discharge rates exceed the capacities of these ponds, Anaconda would either construct additional ponds as necessary or construct a pipeline to route the excess water to the P-10 holding pond as discussed in Sections I.B. and I.C. The additional pond concept seems to be the most environmentally sound due to the possibility of leaks in, or accidental rupture of, the pipeline. Furthermore, the settling pond system should be designed to provide a means for doing maintenance work on any one of the ponds without stopping the operation of the entire system. This would probably consist of adding one or two auxiliary ponds to each system and equipping each pond in the system with by-pass valves so that each pond could operate independently.

In addition to mine dewatering, the proposed mines' water wells would require the extraction of ground water from one or more aquifers in the area. However, because each mine's water requirements are modest, this additional utilization of ground water should not be a significant impact.

The aquifers in the area should not be disturbed significantly by subsidence of the strata overlying the mining voids since such subsidence should not be excessive or extensive as discussed in Section II.A.5.

3. Water Quality

Water quality data for the surface waters in the Jackpile-Paguate area are scarce. According to a study conducted by the U. S. Environmental Protection Agency (EPA) in 1975, stream samples taken from the Rio Paguate and the Rio Moquino (Table 1, Appendix VIII) showed a definite increase in Radium-226 (Ra^{226}) and selenium concentrations downstream from the Jackpile mining operation indicating that precipitation runoff from the disturbed land surface adds radiochemical bearing solids to these streams. However, it should be noted that only one sample was taken at each location, and that the radium concentrations were less than 5 pCi/l which is less than the State of New Mexico's standard of 30 pCi/l. Furthermore, the selenium concentration of the Paguate Reservoir and the Rio San Jose were less than detection limits (EPA, 1975, p. 31, 33, 35).

The proposed action would have very little effect on surface water quality due to the absence of any major surface water sources in the proposed mining area. At its closest point, the Rio Paguate is about 2 miles from the proposed mines. Surface preparation, road construction, waste rock storage, and possibly reclamation work could increase the sediment loads of the small dry arroyos in the area during surface runoff; however, this should be of minor consequence since its time duration would be short and it would have little or no effect on the Rio Paguate. Surface runoff over the waste rock stockpiles could result in the transport of radiochemical species a short distance from the mines. Adequate protection could be provided by using appropriate measures to control surface runoff and by effectively monitoring surface runoff to detect any problem areas.

Degradation of surface waters by the seepage of the radioactively contaminated water from the settling ponds would be prevented by lining the ponds with an impervious clay and/or plastic sheeting. The New Mexico EIA does not require the use of seepage monitoring wells with lined settling ponds, and the sewage lagoons would comply with state standards. Although a failure of the sewage lagoons' or settling ponds' impoundments, caused by excessive surface runoff for example, would be unlikely, adequate measures should be taken to protect against this possibility. This would probably consist of constructing berms around these areas to divert runoff.

By comparing Table 2 and the Water Quality Criteria in Appendix VIII, it can be concluded that the ground water quality in the Jackpile-Paguate area is generally good. The Table 2 values that are outlined indicate areas where the water quality standards are not met.

During the EPA study conducted in 1975, four wells in the vicinity of the Jackpile-Paguate open-pit mining operations were sampled with concentrations of Ra^{226} ranging from 0.18 to 3.7 pCi/l (Figure 1, Appendix VIII). The lowest value (0.18 pCi/l) was recorded at well #233 which is the Paguate municipal water supply. The other wells, believed to be former uranium exploration holes equipped as water wells, are the property of The Anaconda Company and are used to supply potable water and water for equipment washing, etc. The quality of the water from these three wells is probably representative of the Jackpile Sandstone unit of the Brushy Basin Member of the Morrison Formation, the principal ore bearing unit in the Laguna District, but the water may contain elevated levels of radium due to uranium mining activities. The high value of 3.7 pCi/l exceeds the U. S. Public Health Service Drinking Water Standard of 3 pCi/l and was recorded at the Jackpile New Shop Well which is a source of potable and nonpotable water. The EPA subsequently recommended that the continued consumptive use of this water be stopped (EPA, 1975, p. 57). Further sampling by Anaconda (Table 3, Appendix VIII), however, indicates an Ra^{226} concentration of 1.0 pCi/l in the water from this well.

None of the wells sampled by the EPA were above the maximum permissable concentrations for the other common isotopes of uranium, thorium, and polonium (EPA, 1975, p. 6), but the Paguate water supply contained the maximum recommended level for selenium (0.01 mg/l)(EPA, 1975, p. 59). Although the EPA noted that the impacts of mining on ground water quality downgradient from the mining operations were unknown due to the lack of adequate monitoring wells, it also stated "No adverse impacts from mining on the present water supply source for Paguate are expected." (EPA, 1975, p. 6).

Ground water seeping into the P-15 and P-17 mine workings would become radioactively contaminated because the primary minerals to be mined would be exposed to the oxidizing conditions created by the excavation of the workings. Leaching of the very low grade mineralization remaining in the rocks surrounding the mined out areas would also occur. Both of these conditions would result in the mines' discharge waters having radioactive concentrations greater than recommended limits. Mine discharge water impounded within the Paguate Pit contained 190 pCi/l of radium and 170 pCi/l of uranium in 1970 (EPA, 1975, p. 6). This radiological contamination would require that the mines' discharge waters be impounded in the mines' settling ponds for subsequent evaporation of the liquid portion. Sediments that would collect in the ponds would be removed periodically and transferred to ore or waste stockpiles depending on their U_3O_8 content. It is anticipated that the amount of water to be impounded at each mine would be small as discussed in Section II.C.2.

Following the termination of mining operations in the P-15 and P-17 areas, ground water accumulating in the voids created by the mine workings would also become radiologically contaminated. However, the impervious nature of the shales above and below the Jackpile sandstone unit should prohibit substantial vertical migration of this water, and typical changes in the lithologic character of the unit should tend to restrict and localize lateral migration (Mudgett, P-10, 1975, p. 12).

The radioactive contamination of ground water in the proposed mining area should not be a major adverse impact due to the small amount of water that would probably be encountered. However, additional protection for the area's ground water resources could be provided by using an adequate monitoring system to determine the interactions between the aquifers and the mining operations. This would probably consist of completing several wells in the proper strata at different locations around each mining area.

Degradation of the area's ground water by the infiltration of contaminated surface water should be very minor due to the relatively low amount of surface runoff occurring in the area and the lithologic characteristics of the strata. Measures used to prevent surface water contamination, as discussed above, should be adequate to also prevent ground water contamination from such events as failure of the sewage lagoons and settling ponds impoundments, seepage, etc.

D. Land Use

1. Land Use in Lease Area

All of The Anaconda Company's leases are used for mining purposes except for a small centrally located housing area for about thirty key mine personnel. This area is on Lease 1, well removed from the surface mining activities. The property is posted and fenced at all points of eacy access, and a security guard station on the principal access road is manned 24 hours a day (Mudgett, P-10, 1975, p. 5). There are no residences in the proposed mining area.

Lease 1, which is also called the Jackpile Mining Lease, contains the company's operating open-pit uranium mines, the Jackpile and Paguate Pits, as shown on Map G. Although both pits are separate mining operations, they are commonly referred to as the Jackpile-Paguate Open-Pit Mine, and they occupy an area of something less than 12 sections in Townships 10 and 11 North, Range 5 West, N.M.P.M. (The Anaconda Company, 1973, p. 1). The Jackpile ore deposit, which outcropped on the south side of a low mesa, was discovered in November 1951 and active mining began in 1952 (Moench and Schlee, 1967, p. 87). The Paguate ore body, a short distance west of the Jackpile, was discovered by core drilling in June 1956, and ore was being mined by 1963 (Moench and Schlee, 1967, p. 97). The mines are currently operating without an approved mining plan (or plans), but, as discussed in Section I.F., The Anaconda Company is presently drafting a comprehensive mining and reclamation plan for these operations to conform with 30 CFR Part 231 and 25 CFR Part 177.

Mining of the Jackpile and Paguate deposits is accomplished using conventional open-pit methods using rotary blasthole drilling rigs, ammonium nitrate-fuel oil blasting agents, electric shovels, and diesel powered front-end loaders and haulage trucks. The ore is stockpiled, blended, and then shipped by rail (AT&SF) to the compny's Bluewater Mill about 50 miles to the west (See Section I.D.). As of 1973, about 11,300,000 tons of ore had been mined and milled resulting in 57,676,900 pounds of yellowcake (U_3O_8). At that time 8,314,700 tons of remaining ore reserves were indicated, and it was estimated that the mining of these reserves would be completed sometime during the period of 1983 to 1985. In 1973, it was expected that about 24% of the indicated remaining reserves would be mined by underground methods (The Anaconda Company, 1973, p. 2-4).

The Jackpile Mining Lease also contains two underground mine workings (See Map G). The Woodrow Mine, about 1 mile east of the Jackpile Pit, was discovered in 1951. Mining of the deposit, which was in a nearly vertical sandstone pipe, began in 1954 through a vertical shaft and ended in 1956 when the square-set timbering collapsed. The mine produced about 5,500 tons of uranium ore (Moench and Schlee, 1967, p. 96). The H-1 Mine, a small adit mine, was developed for the extraction of about 38,000 tons of uranium ore by longwall and sub-level stoping methods. Operations began in March 1973 under an approved mining plan, and the ore was subsequently exhausted and the mine abandoned in April 1975 (The Anaconda Company, H-1, 1972, p. 1-3).

The P-9-3 and P-11 workings were planned to be small adit mines developed from the north and east walls of the inactive P-9-1 open pit for the extraction of about 81,000 tons of uranium ore by a modified sub-level room-and-pillar stoping method. The operations were approved November 17, 1975, (Mudgett, P-9-2, 1975, p. 1-2), but they have subsequently been postponed because it may be feasible to mine the ore with open-pit methods (Gibbs, 1976, oral communication).

Lease 4 contains various underground mine workings as well as some facilities for the Paguate Pit operations (Maps B & G). The P-9-2 Adit Mine Project, approved in February 1974, was developed from the south wall of the small, mined-out P-9-1 open-pit for the extraction of about 58,000 tons of uranium ore by longwall and sub-level modified room-and-pillar stoping. The project produces between 100 and 150 tons of ore per day (Mudgett, P-9-2, 1973, p. 1). The P-10 Mine (Map B) is currently producing about 700 tons of uranium ore per day by modified room-and-pillar stoping with sublevel track haulage. Access to the mine is provided by an inclined shaft. The mining plan for the project was originally approved August 31, 1973, with major changes in the plan being approved October 19, 1973. Further changes in the plan which provided for the mining of ore in the P-7 area by extending the P-10 workings were approved December 12, 1975. According to The Anaconda Company, the P-9-2 area will be mined out by about mid-1977 while the P-10 and P-7 ore reserves will be exhausted by mid-1982 (Gibbs, 1976, oral communication).

The proposed mining operations would not affect the present use of the involved lands because the leases are used exclusively for mining purposes. This area has been a well known mining district since about 1956 when the Jackpile Mine was the largest single producer of uranium in the United States, and possibly in the world (Moench and Schlee, 1967, p. 1). The proposed mining area has been impressed with numerous drilling sites and access roads from exploration and development drilling activities.

2. Land Use in the Surrounding Areas

The lands adjacent to The Anaconda Company's mining leases are used exclusively by members of the Laguna Tribe for residential and livestock grazing purposes. The primary domestic animals encountered are sheep and cattle, but a few horses do roam in the areas. Agriculture is severely limited by the lack of sufficient precipitation and is probably restricted to small garden plots worked by residents of the areas.

The community closest to the proposed mining area is the small Laguna Indian village of Paguate (Map A) which is about 2 miles to the north. As of January 1, 1975, the census showed a resident and non-resident population of 1,383 for Paguate (Starcevich, 1976, oral communication); however, the actual resident population for the village is close to 300 (The Anaconda Company, 1973, p. 9). Paguate has no retail or public service facilities such as restaurants, service stations, motels, schools, hospitals, etc., except for one very small general merchandise type store which is extremely limited in available goods. Approximately 2 to 5 miles north of Paguate are the even smaller settlements of Bibo, Cebolleta, Cebolletita, and Moquino.

The Indian village of Laguna, or the Pueblo of Laguna, is located about 5 miles south of the proposed mining area (Map A). This small village, as of January 1, 1975, had a resident and non-resident population of 1,449 although, as in the case of Paguate, the actual resident population is probably much less. There are more services here than in Paguate but they are still limited to a few small stores and service stations. The Laguna-Acoma High School and an elementary school are located in Laguna (Starcevich, 1976, oral communication).

The closest town offering a wider variety of goods and services is Grants which is about 30 miles west of Laguna via Interstate Highway 40 (Map A). Grants is an incorporated city of 8,768 (1970 census), and about 3 miles west of Grants is the village of Milan which has a population of 2,185 (1970 census) (ISRAD, 1972, p. 22-23). In 1967, Grants-Milan had 130 of the 327 retail establishments in Valencia County (ISRAD, 1972, p. 87), and in 1970, Grants had 23% of the county's labor force (NMEI, 1975, p. 90). Grants also has a hospital and a branch campus of New Mexico State University (NMEI, 1975, p. 125).

Albuquerque, the county seat of Bernalillo County, is about 46 miles east of Laguna via I-40 (Map A). This metropolitan city of 243,751 (1970 census) offers a full range of goods and services for both private and commercial needs (ISRAD, 1972, p. 22-23).

Access to the Paguate area is provided by paved State Highway 279 which joins Interstate Highway 40 at Laguna (Map A.). I-40 connects Laguna with Grants-Milan to the west and Albuquerque to the east. Greyhound Bus Lines, Inc., and Continental Trailways, Inc., stop daily for passengers in Grants on their routes from Albuquerque to Los Angeles, California, and passenger and freight rail service is provided by the AT&SF railroad which also passes through Grants-Milan and Albuquerque. Although Grants has an airport, Albuquerque has the closest commercial air service (NMEI, 1974, p. 20).

Recreation in the Paguate-Laguna area is confined primarily to outdoor activities such as picnicking, camping, sight-seeing, and hunting, the majority of which are conducted in the Cibola National Forest on and to the west of Mount Taylor. These activities can be classified as seasonal and intense (NMEI, 1974, p. 16, 34). Camping, fishing, boating, and swimming are permitted at Bluewater State Park (Bluewater Lake) which is about 21 miles west of Grants via State Highway 412. The major recreational centers in the area are Grants and Albuquerque.

Due to their size, nature, and location, the proposed mining operations would not have any effects on land use in the surrounding areas. The local communities may be affected to a minor extent, and these effects are discussed in Section II. F. No impacts on the local transportation services would be expected since ore shipment would be by company equipment and existing rail facilities and schedules.

3. Historical and Archaeological Sites

There are no historical or archaeological sites on or near the leased lands according to the Southern Pueblos Agency of the Bureau of Indian Affairs or company sources (Mudgett, P-10, 1975, p. 6). Although some type of archaeological clearance must have been obtained for the company's exploration activities in the proposed mining area, a search of the files of the Bureau of Indian Affairs, National Park Service, Geological Survey, and The Anaconda Company has failed to produce any documentation of such a clearance. Appendix IX contains an archaeological survey report from the School of American Research for areas within the company's mining leases that would be affected by the expansion of Anaconda's open-pit and underground mining operations. This survey does not cover the P-15 and P-17 areas and is provided for general information purposes only. Area A-7, in which no materials of archaeological or historical significance were found, is the closest parcel of land to the proposed mining area that was surveyed.

Unless evidence of a previous archaeological clearance can be produced, The Anaconda Company would, in order to comply with current regulations for the protection of antiquities, need to obtain the proper archaeological clearance. This would consist of having a survey of the area conducted and the resulting report submitted to the National Park Service for approval and granting of clearance. This requirement would have to be met before surface operations could commence, and the company is currently in the process of meeting this prerequisite.

The Laguna Pueblo and the San Jose de la Laguna Mission and Convento (in the Pueblo) at Laguna are listed in the National Register of Historic Places, but both are well removed from the proposed operations (about 5 miles) and would not be affected. The Grants Lava Flow which extends about 25 miles south of Grants between State Highway 117 on the east and 53 on the west (Map A) is eligible for listing in the National Registry of Natural Landmarks, but it too is well removed from the proposed projects.

4. Scenery and Aesthetics

The proposed action would not affect the scenic or aesthetic values of any of the prominent landmarks in the area such as Mount Taylor, the Laguna Pueblo, Mesa Chivato, and the Cibola National Forest. However, the appearance of the northeast flank of Black Rim Mesa would be affected significantly by the presence of the mines' surface facilities which would be visible totally or partially from Highway 279. The mine buildings, roads, power lines, and vent hole equipment would have only a minor impact, but the mine yards, sewage lagoons, and settling ponds would have a significant impact due to the considerable cut and fill required for these facilities by the steeply sloping land surface. The mine workings themselves would have no effect since they would be underground.

This adverse scenic effect would be lessened to a degree by the fact that the facilities would not be silhouetted against the skyline and could be lessened further by painting the larger structures to match the background colors.

5. Reclamation Potential

The reclamation potential of the land in the area has not been adequately determined, but the writer feels that this potential is only poor to fair. This estimate is due to the fact that most uranium related reclamation work (primarily in uranium exploration) has met with only limited success due to soil characteristics and the lack of sufficient moisture (precipitation). These conditions would also surely determine the results of any revegetation programs in the Jackpile-Paguate area.

The Anaconda Company is currently conducting revegetation experiments on inactive waste dumps in order to adequately assess the land reclamation potential. The U. S. Conservation Service has recommended such seed mixtures as sideoats, gramma grass, western wheatgrass, and chamisa brush, and test plots have been planted for observation (The Anaconda Company, 1973, p. 7). Continued experimentation by Anaconda and other companies in northwestern New Mexico's coal and uranium industries should improve the land's reclamation potential by providing new and improved reclamation techniques.

E. Fauna and Flora

Due to the intense mining activity in the adjacent Jackpile-Paguate area and the absence of any perennial surface water in the P-15 and P-17 area, wildlife in or near the project area is limited to small rodents (rabbits, mice), small predators (foxes, coyotes, bobcats), small birds (finches, sparrows, jays), insects, and reptiles common to northwestern New Mexico. The presence of a stable, resident predator population is doubtful because of human presence and activity, and most of the birds are also probably transient inhabitants. The largest wild animal in or near the area are mule deer which inhabit the slopes of Mount Taylor and the mesas to the north (The Anaconda Company, 1973, p. 9). No endangered species are known to be present in the area as residents (Mudgett, P-10, 1975, p. 6). Several almost wild horses that belong to the Laguna Indians roam within the proposed mining area (Gibbs, 1976, oral communication).

The proposed operations would not have a significant impact on the wildlife resources of the area because of the small number of actual permanent wildlife residents. A small amount of habitat would be disturbed throughout the lives of the operations (about 41 acres) resulting in the displacement of a small amount of wildlife, but there is ample habitat in the surrounding areas to accomodate any displaced species. The mine yards, settling ponds, sewage ponds, and vent hole areas would be fenced throughout the operations' lives to keep out the larger species, and the settling ponds and sewage lagoons should not be detrimental to any waterfowl that might be attracted to them. Traffic on the haulage and access roads could be a hazard to wildlife, but this should not be significant.

If the reclamation program was successful in establishing grassland vegetation in the area, there could be a slight decrease in the number of woodland species and a corresponding increase in the number of grassland species, but substantial reinhabitation of the area would probably not occur until completion of the reclamation and revegetation program. No significant alteration of species composition would be expected since the amount of habitat involved is quite small. The establishment of grassland vegetation would be beneficial to domestic animals, and possibly to wildlife, by improving grazing conditions.

The vegetation in the lowest valley and mesa areas around Mount Taylor is characteristic of the Upper Sonoran life zone consisting of flowers, grasses, sagebrush, and composites such as goldenrod, rabbitbrush, and sunflowers. The trees in this zone generally occur on hillsides and mesas and consist of one-seeded juniper, the nut pine (piñon), and the cane cactus. Greasewood is common on alluvial flats adjacent to watercourses, and there are groups of the common valley cottonwood (Hunt, 1937, p. 37).

The rough boulder strewn surface of the proposed mining area supports a moderate but scattered growth of native grasses and desert shrubs and a moderate to heavy growth of juniper trees. There are widely scattered occurrences of cacti (Photos A, H, I, J, K). Past exploration and development drilling activities have impressed the area with numerous drill sites and access roads.

The proposed operations would result in the destruction of the vegetation on about 41 acres of the land surface. This should not be a major impact since the vegetative cover is moderate and scattered as noted above. The reclamation program would attempt to establish herbaceous growth on the area, and the range conditions on the 41 acres would be greatly improved if the program was successful. If herbaceous growth could not be established, it might be possible to revegetate the area with native species, such as juniper seedlings. The writer has no knowledge of any such attempt being made in other uranium related reclamation programs; however, during the inspection of various company's exploration activities, it has been observed that natural revegetation by native species usually begins within an intermediate time period after the completion of leveling and grading operations (estimated at 3 to 6 months).

F. Socio-Economic Conditions

The proposed operations should not cause a large influx of new people into the area since Anaconda would use local labor as much as possible. In compliance with lease terms, Anaconda gives the Laguna Indians priority in employment at all its Jackpile-Paguate mining operations, and, as of October 1975, about 90% of the company's 372 mine personnel were Lagunas (Mudgett, P-10, 1975, p. 5). It is anticipated that the majority of the 275 employees required by the mines would be supplied by the local populace although some positions could be filled by employees transferred from the completed P-9-2 operations. A few permanent employees could be expected to move into the area, and shaft sinking and mine development personnel would relocate in the area temporarily.

Any socio-economic impacts on the villages of Paguate and Laguna should be very minor due to the very limited supply of services available in these communities. Some Lagunas employed at the mines could want to relocate in Laguna or Paguate which could require additional housing, but this should not be of major consequence. The Anaconda Company has cooperated with the Laguna Tribe in housing construction in Paguate.

Any major socio-economic impacts would most likely fall on the city of

Grants since any new permanent workers, and the temporary labor force, would probably relocate there. According to recent newspaper articles, Grants-Milan is having trouble in providing adequate housing and public services for a population increasing due to the expansion of uranium activities in this area. Although the influx of permanent and temporary workers for the proposed mines could put an additional strain on these services, the small number of workers expected to relocate should not create a significant effect. The mitigation of cumulative socio-economic impacts is the responsibility of appropriate public agencies such as city, county, and state planning commissions.

The proposed operations should have very little effect, if any at all, on the metropolis of Albuquerque which would be capable of managing any such impact.

The most significant socio-economic impact resulting from the proposed action would be the generation of new income. According to lease terms, the company would pay royalties on the ore mined to the Pueblo of Laguna; as of November 1973, the Jackpile-Paguate mining operations had paid about $25,000,000 in such royalties to the Pueblo (The Anaconda Company, 1973, p. 3). Direct employment during the mines' lives would also result in annual disposable income. It is expected that most of this income would be respent within the region which could have a multiplier effect on other sectors of the economy. Additional federal, state, and local taxes that would be paid by Anaconda and its employees should offset any increased governmental costs that would be caused by the proposed action.

Increased income in the area could improve the standard of living for many families, and direct employment could improve the self-esteem and mental health of many people who are currently unemployed or underemployed.

Because the Lagunas would be given preference in hiring, most of the benefits would be directly, or indirectly, advantageous to the Laguna Indian Tribe, as would the royalty benefits. Although many experienced workers would be unemployed at the close of operations, the training and experience acquired should help these workers find new jobs more easily.

The proposed action should not have any significant effects on the cultural values of the area or of the Laguna Indians in particular. It seems that all Indians have the general belief that nature is a strong force to which man must adapt rather than control. Although this belief causes a reluctance to support activities exploiting the Indians' natural resources, it also provides strong support for the restoration of the land following such activities. It also seems that although Indians do value work, they work to maintain their families and themselves, not to achieve social prestige. This evidently causes a strong tendency to reject monetary incentives once a relatively low level of income is reached. Indian males evidently often reject the role of "breadwinner" since it involves accepting wage labor, thus increasing the possibility of alcoholism and social dysfunction which can result in increased absenteeism and possibly the total rejection of work. According to Anaconda officials, absenteeism among the company's Laguna employees is quite high which necessitates the hiring of extra personnel who would normally not be required.(Gibbs, 1976, oral communication).

G. Health and Safety

Health and safety at each of the mines, both surface and underground, would be controlled by the company's safety personnel in accordance with the standards and regulations of the New Mexico State Mine Inspector and the Mining Enforcement and Safety Administration. Periodic inspections of the operations by authorized personnel from these regulatory agencies would assure compliance with the applicable regulations and standards. The Anaconda Company currently operates active safety programs at both its mining and milling operations.

The proposed action would have only one possible effect on local health and safety, that being the possible hazard that could be created by vehicular traffic on the access and haulage roads, especially at the junctions of these roads with State Highway 279 (MapB). A relatively heavy flow of traffic would occur at shift changes on the access road and on Highway 279 between Laguna and Paguate, thus possibly creating an intermittent traffic hazard on these roads and their intersection. Ore haulage trucks would cross Highway 279 on their way to the P-10 stockpile areas which could create a traffic hazard at the intersection of the haulage road and Highway 279.

Adequate posting of proper warning signs and/or devices at and around the involved intersections should sufficiently reduce hazards at these locations, and the posting and enforcement of appropriate speed limits and warnings on the haulage and access roads should adequately reduce traffic hazards on these routes. The supervision of traffic on Highway 279 is the responsibility of state and local law enforcement agencies.

III. Alternatives to the Proposed Action

A. Alternative Methods

No other mining methods or modification of the proposed method would result in reduced environmental damage or disturbance. Open-pit mining would have a much greater environmental impact because it would require the utilization of much more land surface with the final open-pit being more difficult to backfill and reclaim. In situ leaching (solution mining) of the ore bodies, if technically feasible, would result in lower uranium extraction and possible contamination of ground water due to losses in solution recovery.

The proposed action could be refused, but this would prevent the production of source materials necessary for the generation of electricity by nuclear fission energy. This electricity is needed to alleviate the national energy shortage. Refusal of the proposal would also deprive the Pueblo of Laguna of direct and indirect benefits from potential royalty and direct employment incomes.

B. Mitigating Measures

Should the proposed action be approved as submitted, additional mitigation of the environmental impacts of the action would be provided by the following measures:

1. The effective use of water where practical and possible would keep airborne dust created by the proposed operations to a minimum (e.g. on the access and haulage roads). As discussed in Section II. B.2., The Anaconda Company currently operates a high volume air sampling station on a continuous basis and plans to expand this program by establishing meteorology

monitoring stations and additional air sampling stations.

2. The effective use of water control structures and anti-erosion measures would minimize the possibility of any effects on surface water quality from the proposed operations (e.g., surface runoff over topsoil and waste rock stockpiles). Adequate monitoring of the surface drainages in the mining area would detect any deficiencies and provide a basis for corrective action.

3. The construction of water control structures around the sewage lagoons and settling ponds would protect against the possibility of a failure of one or more of these impoundments and would, therefore, protect against the water pollution which could result from such a failure.

4. Adequate monitoring of the ground water in the mining area would help to determine the interactions between the mining operations and the aquifers and would provide a basis for correcting any deficiencies.

5. The impact of the proposed operations on the appearance of Black Rim Mesa could possibly be mitigated by painting the larger surface structures to match background colors and by immediate revegetation of any disturbed land surface or fill slopes that are visible from Highway 279.

6. Adequate posting of appropriate warning signs and/or devices at and around the intersections of the haulage and access roads and Highway 279 would help reduce traffic hazards at these locations. The posting and enforcement of appropriate speed limits and warnings on the access and

haulage roads would help reduce traffic hazards on these routes.

7. The reclamation and revegetation program would attempt to establish herbaceous growth on the disturbed land surface. If successful, about 41 acres of marginal grazing land would benefit from this program.

IV. Unavoidable Adverse Environmental Effects of the Proposed Action

Subsidence of the strata overlying the underground mine workings could have some surface expression depending on certain combinations of ore depth and thickness, mining extraction, and strength of the overlying strata. It is expected that any subsidence occurring would not be excessive and would not create a significant adverse impact.

The proposed operations would cause a certain amount of dust, but this would not be a major impact and could be minimized by using water. Air pollution from equipment exhaust gases should be insignificant. The mines' atmospheres would be contaminated by blasting fumes, radon gas, and exhaust gases, but the ventilation systems and frequent monitoring by the appropriate regulatory agencies would maintain this contamination within acceptable limits. Any odor problems from the sewage lagoons should be insignificant and controllable by chemical treatment.

Any noise created by the operations would be insignificant due to the absence of any nearby residences.

The extraction of the P-15 and P-17 ore deposits would require the withdrawal of ground water from the Jackpile Sandstone, and the mines' water wells would withdraw additional water from the Brushy Basin or Westwater Canyon Members. This lowering of the ground water levels could cause water level declines in wells and a reduction in the flow of springs within the general vicinity of the mines. In addition, ore extraction would result in radiological contamination of the ground water seeping into the mine workings during the productive lives of the mines and, to a lesser degree, following the termination of all mining operations with minor potential for migration within the Jackpile Sandstone. Surface preparations, waste rock storage, and possibly reclamation operations could affect the quality of surface runoff in the proposed mining area.

The surface facilities of the proposed operations would significantly alter the appearance of the north-east flank of Black Rim Mesa, an effect which would be totally or partially visible from State Highway 279.

Surface construction and preparation associated with the proposed mining operations would result in the temporary disturbance of about 41.1 acres of land surface and the destruction of the vegetation thereon. Any wildlife inhabiting this area, permanently or temporarily, would be displaced, probably until completion of the reclamation and revegetation program.

V. Matrix Analysis

Lease Number Laguna Tribal Lease 4
Lessee (Permittee) The Anaconda Company
County Valencia State New Mexico
Date April 28, 1976
Prepared by Dale C. Jones
Other Agency Representatives ______

EXISTING CONDITIONS / PROPOSED ACTION	Other	Accidents: Structure failure (dams, impoundments, etc.)	Accidents: Geologic related hazards (subsidence, slope failure, etc.)	Accidents: Spills, leaks, explosions	Waste Disposal: XXXXXXXXXXXX	Waste Disposal: Sanitary wastes	Waste Disposal: Solid waste (XXXXXX, waste rock)	Transportation: Other	Transportation: XXXXX	Transportation: Pipelines, conveyors	Transportation: Trucks, vehicular traffic	Mining: Post mining activities (reclamation, etc.)	Mining: XXXXXXXXXXXX	Mining: Storage (product, waste, spoils, water)	Mining: Subsurface excavation	Mining: Surface excavation (XXXXXX site preparation, shafts, etc.)	Construction: XXXXXXXXXXXX	Construction: Structures (mine buildings, etc.)	Construction: Dams, impoundments, water diversions	Construction: Transmission lines, pipelines	Construction: Roads, bridges, XXXXXXXX
Air Pollution						/	/				/	/		/	/	/					/
Noise Pollution											/	/			/	/					
Surface Water Availability																					
Surface Water Pollution		/		/			/					/		/		/					/
Ground Water Availability															/						
Ground Water Pollution		/	/	/								/		/	/						
Existing Land Use												B X									
Surrounding Land Use																					
Historical and Archeological Sites																					
Scenic, Recreational and Aesthetic Values						/	X			/		B X		X		X		/	/	/	/
Endangered Species and Habitat																					
Plant Populations						B /	/			/		B X		/		/			B /	/	/
Animal Populations						/	/				/	B /		/		/			/		/
Nesting, Breeding or Migration Sites																					
Effect on Local Communities																					
Effect on Cultural Values												B X									
Public Health and Safety											/										/
Public Interest																					
Other																					

VI. Determination and Recommendation

From the preceding analysis, it is concluded that the proposed action does not constitute a major Federal action significantly affecting the quality of the human environment in the sense of the National Environmental Policy Act, Section 102 (2)(c). However, it is recommended that when The Anaconda Company submits the comprehensive mining and reclamation plan for all of its Laguna mining operations, an Environmental Analysis should be prepared in order to determine whether or not the cumulative impacts of all the operations do significantly affect the quality of the human environment and, therefore, necessitate the preparation of a site specific or sub-regional Environmental Impact Statement.

It is recommended that the proposed mining and reclamation plan for the P-15 and P-17 Mines be approved if The Anaconda Company will accept the following stipulations as part of the plan.

1. The Anaconda Company will keep airborne dust, especially that created by vehicular traffic on the haulage and access roads, to a minimum by using adequate amounts of water. The frequency of water application would probably range from once or twice daily during dry seasons to fewer applications during times of natural precipitation.

2. The Anaconda Company, prior to commencing operations, will submit to the Area Mining Supervisor for his approval, a detailed plan for the monitoring of surface runoff within the proposed mining area. This plan will provide for the monitoring of both the quantity and quality of the surface runoff in order to determine the nature and extent of the operations's effects on the surface water in the area and to provide a basis for

determining any necessary corrective actions.

3. The Anaconda Company will implement appropriate measures, as necessary, to prevent erosion and control surface runoff on any of the disturbed land surface. The monitoring of the surface runoff in the mining area would help to determine the adequacy of these measures.

4. Prior to commencing operations, The Anaconda Company will submit to the Area Mining Supervisor for his approval, a detailed plan for the monitoring of the ground water both up - and down-gradient of the P-15 and P-17 ore bodies. This plan will provide for the monitoring of both the quantity and quality of the ground water in order to determine the interaction between the mining operations and local hydrology.

5. The results of the water monitoring programs will be submitted quarterly (i.e., every 3 months) to the Area Mining Supervisor.

6. Prior to commencing operations, The Anaconda Company will submit to the Area Mining Supervisor for his approval, a detailed plan for the settling pond systems at each mine. This plan will detail the construction of these systems and will provide for at least one auxiliary pond in each system and the use of appropriate by-pass equipment to allow each pond to be operated independently. The plan will also describe in detail the measures to be used to divert surface runoff around the settling ponds and sewage lagoons (i.e., the mesaures to be used to protect these

impoundments from accidental failure).

7. Prior to commencing operations, The Anaconda Company will obtain the proper archaeological clearance for the area to be affected by the mining operations, a copy of which will be submitted to the Area Mining Supervisor.

8. Appropriate but practical measures will be taken to camo-flauge the mines' surface facilities as much as reasonably possible.

9. Adequate warning signs and/or devices will be placed at appropriate distances from the intersections of the haulage and access roads and State Highway 279 to alert traffic to the possible hazards at these locations. Appropriate speed limits and warnings will be posted and enforced on the access and haulage roads.

References

Cleveland, James E., Superintendent of Environmental and Industrial Hygiene, Kerr-McGee Corporation, New Mexico Operations: Grants, New Mexico, oral communication, October 15, 1975.

Dinwiddie, George A., 1963, Ground Water in the Vicinity of the Jackpile and Paguate Mines, in Geology and Technology of the Grants Uranium Region: New Mexico Bureau of Mines Memoir 15, p. 217-218.

Gibbs, Clifford M., Superintendent of Underground Operations, The Anaconda Company, New Mexico Operations, Uranium Division: Grants, New Mexico, oral communications, April 28, 1976, June 15, 1976.

Gregg, George, Meteorologist in Charge and Climatology, National Weather Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce: Albuquerque, New Mexico, oral communication, June 11, 1976.

Hilpert, Lowell S., 1969, Uranium Resources of Northwestern New Mexico: Geological Survey Professional Paper 603, 166 p., 4 pls., 20 figs., 16 tables.

Hunt, Charles B., 1936, The Mount Taylor Coal Field, pt. 2 of Geology and Fuel Resources of the Southern Part of the San Juan Basin, New Mexico: U. S. Geological Survey Bull. 860-B, p. 31-80.

Institute for Social Research and Development (ISRAD), 1972, New Mexico Statistical Abstract: Bureau of Business Research, University of New Mexico, Albuquerque, New Mexico, 98 p., 90 tables, 7 maps.

Moench, Robert H., 1963, Geologic Limitations on the Age of Uranium Deposits in the Laguna District, in Geology and Technology of the Grants Uranium Region: New Mexico Bureau of Mines Memoir 15, p. 157-166.

Moench, Robert H. and Schlee, John S., 1967, Geology and Uranium Deposits of the Laguna District, New Mexico: Geological Survey Professional Paper 519, 117 p., 9 pls., 39 figs., 16 tables.

Mudgett, Philip B., 1975, Environmental Impact Analysis, Proposed Changes, P-10 Mining Plan, The Anaconda Company, Laguna Tribal Uranium Lease No. 4, Paguate, New Mexico: U. S. Geological Survey, Conservation Division, Carlsbad, New Mexico, 18 p.

Mudgett, Philip B., 1975, Environmental Impact Analysis, The Anaconda Company, P-9-2 Adit Mine Project-Proposed Changes, Valencia County, New Mexico: U. S. Geological Survey, Conservation Division, Carlsbad, New Mexico, 6 p.

Mudgett, Philip B., 1973, Environmental Impact Analysis, Proposed Mining Plan, The Anaconda Company's P-9-2 Underground Uranium Mine, Valencia County, New Mexico: U. S. Geological Survey, Conservation Division, Carlsbad, New Mexico, 5 p.

References

New Mexico Environmental Improvement Agency (NMEIA), Water Supply Regulation Section, 1974, New Mexico Public Water Supplies Chemical Data, Minor Communities: Santa Fe, New Mexico, 217 p.

New Mexico Environmental Institute (NMEI), 1974, An Environmental Baseline Study of the Mount Taylor Project Area of New Mexico: Project 3110-301, Las Cruces, New Mexico, 244 p., 49 tables, 39 Figures, Appendices.

New Mexico Environmental Institute (NMEI), 1975, An Environmental Baseline Study of the Mariano Lake Project Area of New Mexico: Project 3110-304, Las Cruces, New Mexico, 275 p., 81 tables, 29 figures, Appendices.

Rinaldi, Martin J., Program Manager, Monitoring and Surveillance Section, Air Quality Division, New Mexico Environmental Improvement Agency: Santa Fe, New Mexico, written communication, May 26, 1976.

Starcevich, Dianne, New Mexico State Census, Southern Pueblos Agency, Bureau of Indian Affairs, Department of Interior, United States Government: Albuquerque, New Mexico, oral communication, June 14, 1976.

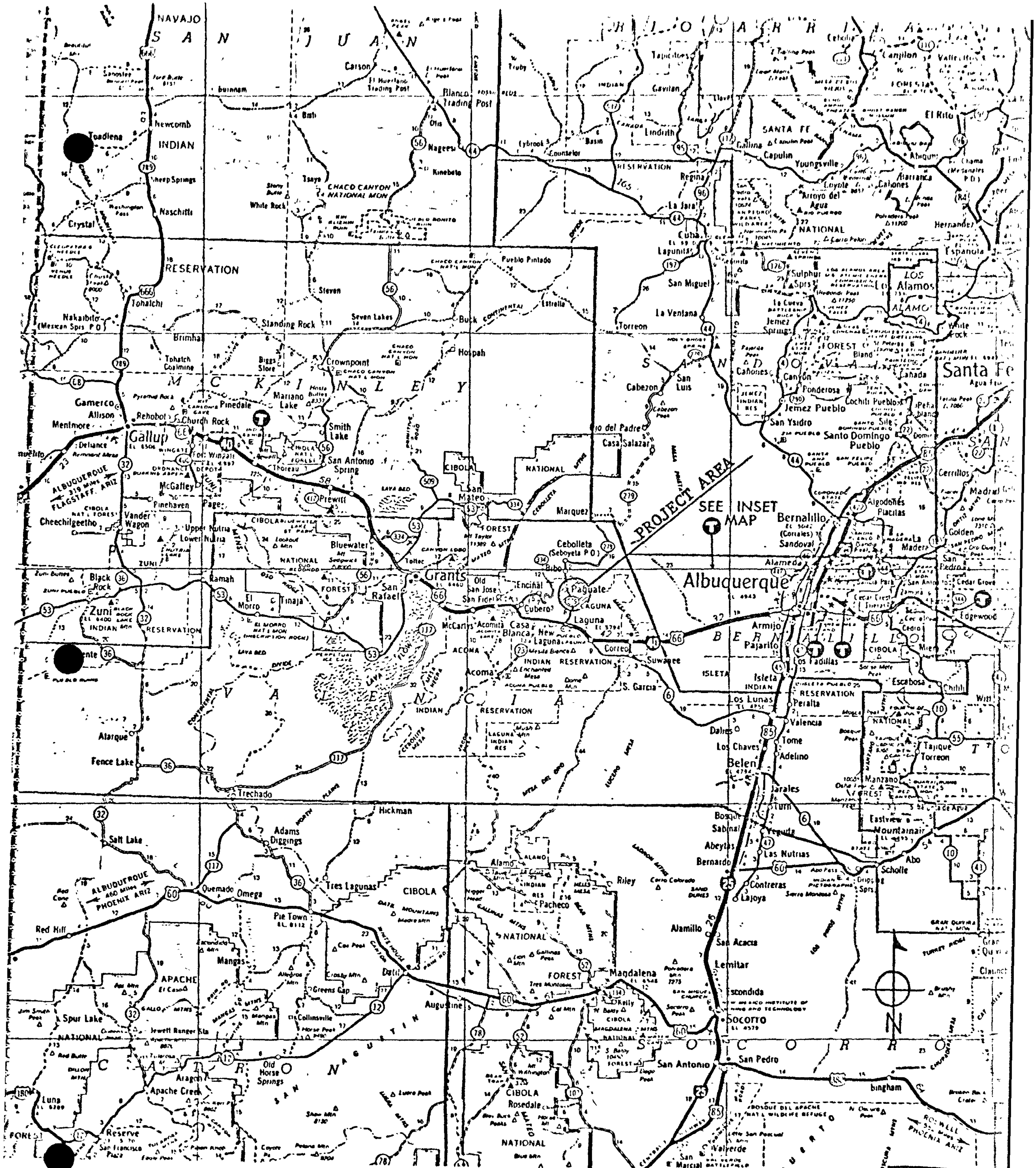
The Anaconda Company, 1973, Mining Plan for the Jackpile-Paguate Open-Pit Mine (Rough Draft), Laguna Indian Reservation, Valencia County, New Mexico: Grants, New Mexico, 11 p.

The Anaconda Company, 1972, Mining Plan for the H-1 Mine, Laguna Indian Reservation, Valencia County, New Mexico: Grants, New Mexico, 4 p.

U. S. Environmental Protection Agency, 1975, Water Quality Impacts of Uranium Mining and Milling Activities in the Grants Mineral Belt, New Mexico: EPA 906/9-75-002, Region VI, Dallas, Texas, 70 p., 12 figs., 9 tables.

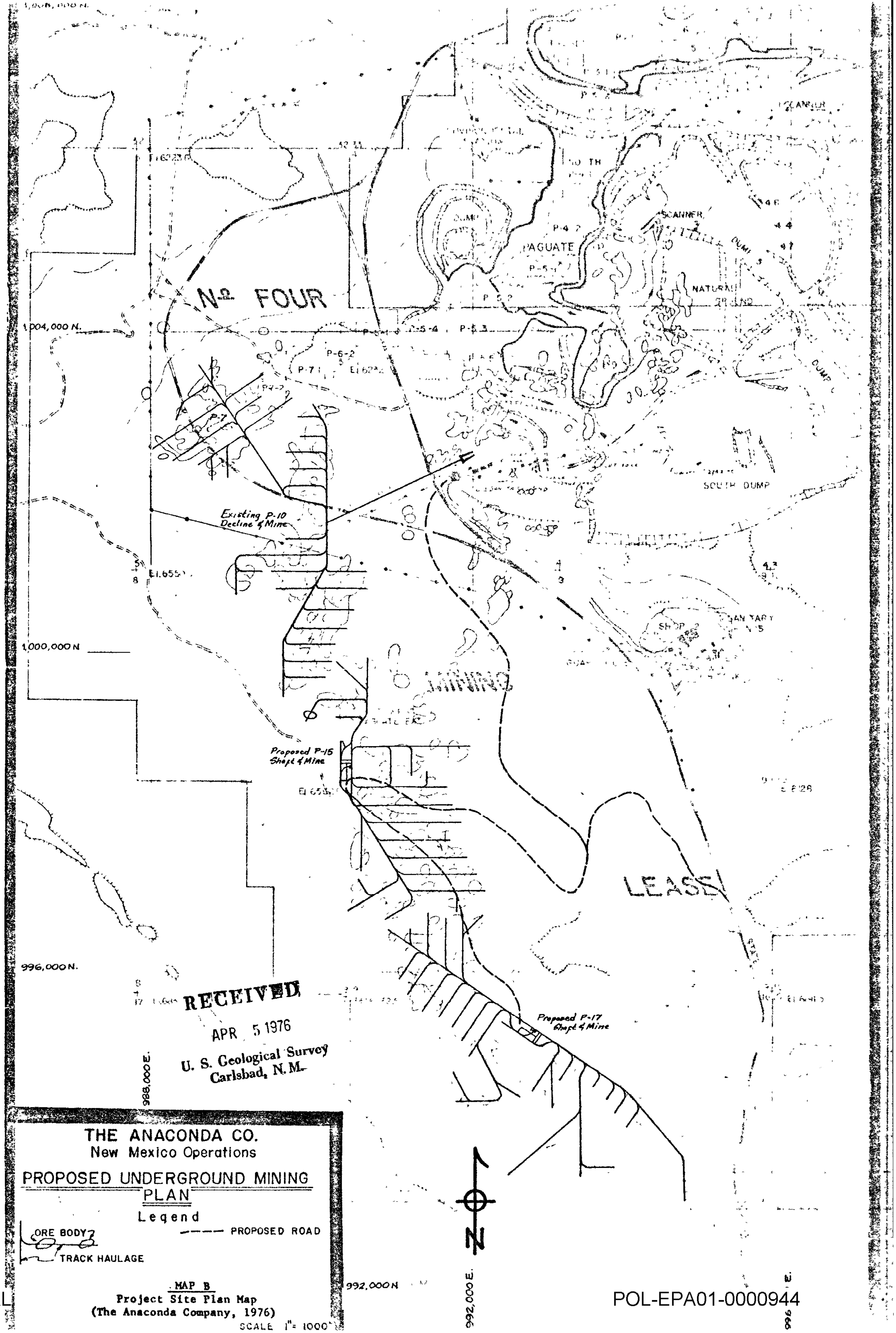
White, Boyd, Principal Assistant, Meteorologist in Charge and Climatology, National Westher Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce: Albuquerque, New Mexico, oral communication, June 23, 1976.

MAPS

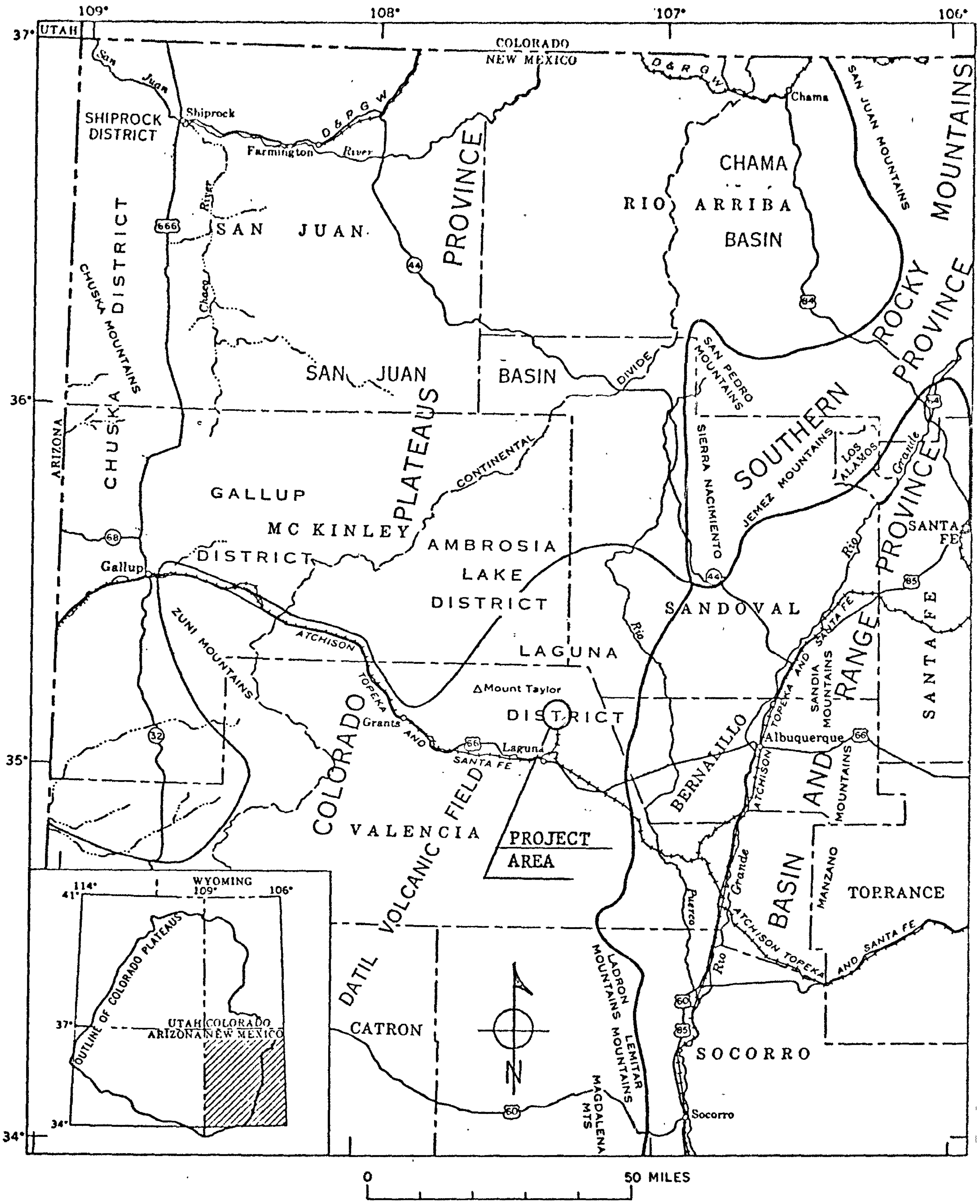


MAP A

Project Area Location Map
(Texaco Touring Map of New Mexico, 1957)

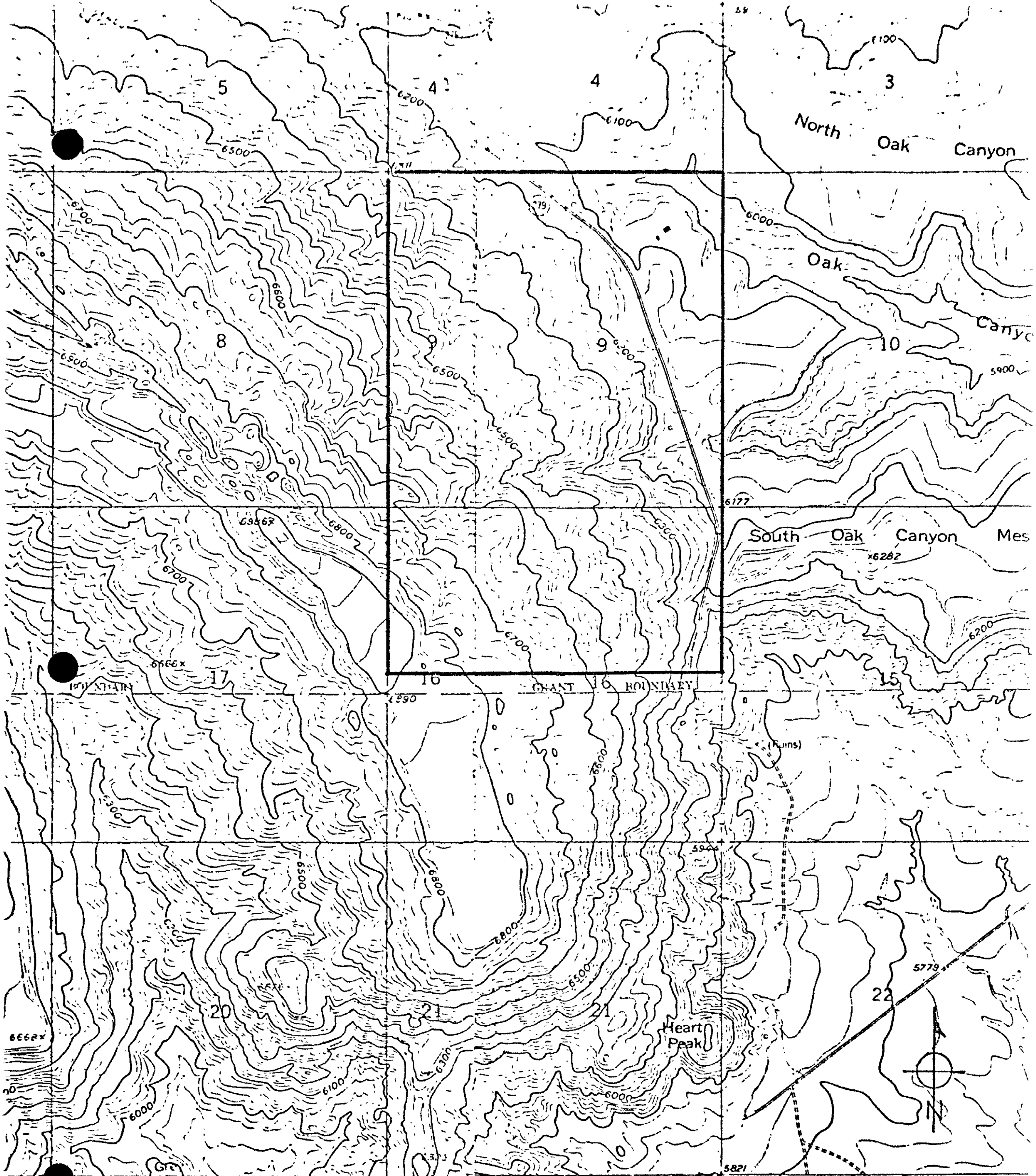


MAP B
Project Site Plan Map
(The Anaconda Company, 1976)



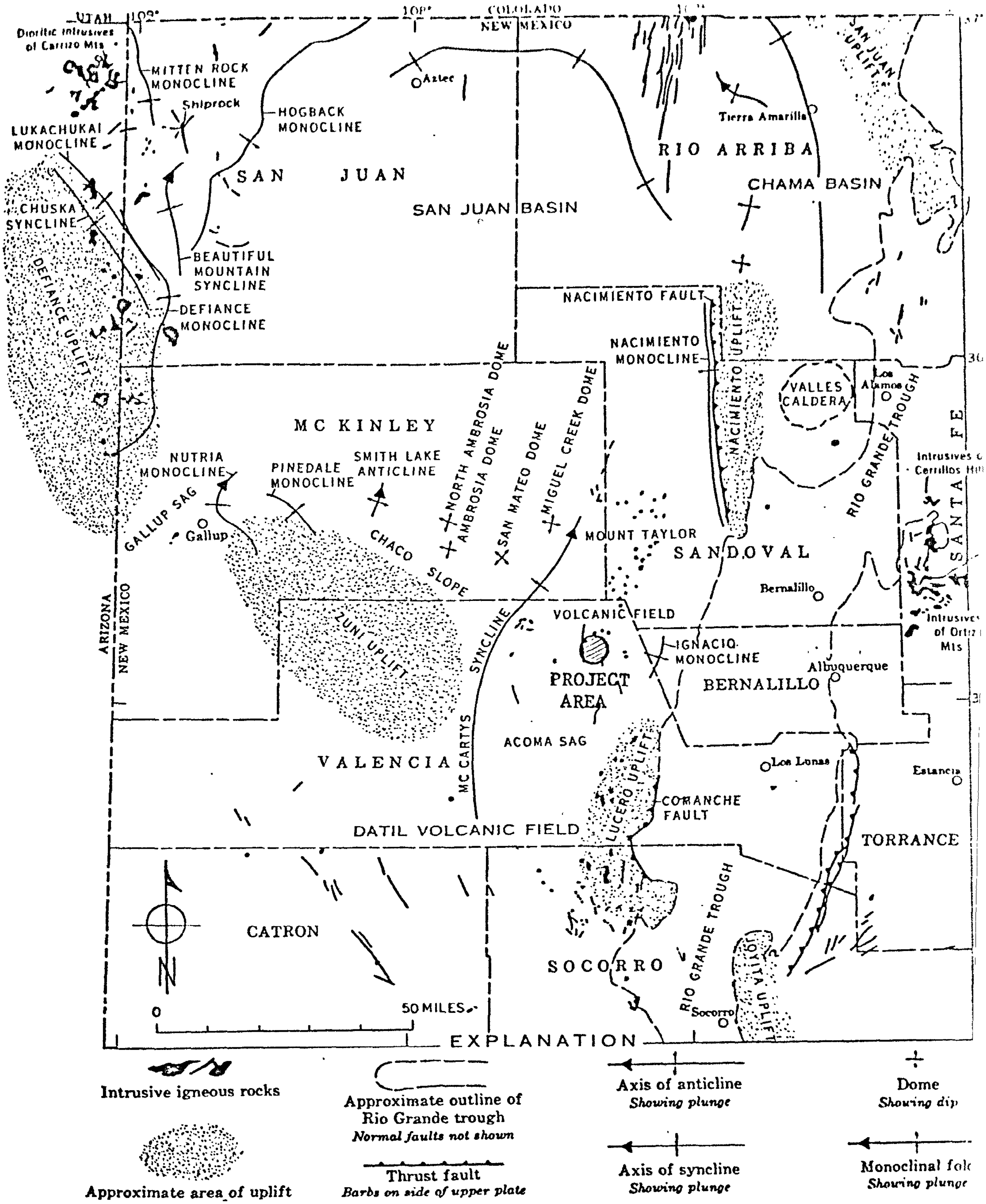
MAP C

Physiographic Map of Northwestern New Mexico
(Hilpert, 1969, p. 3)



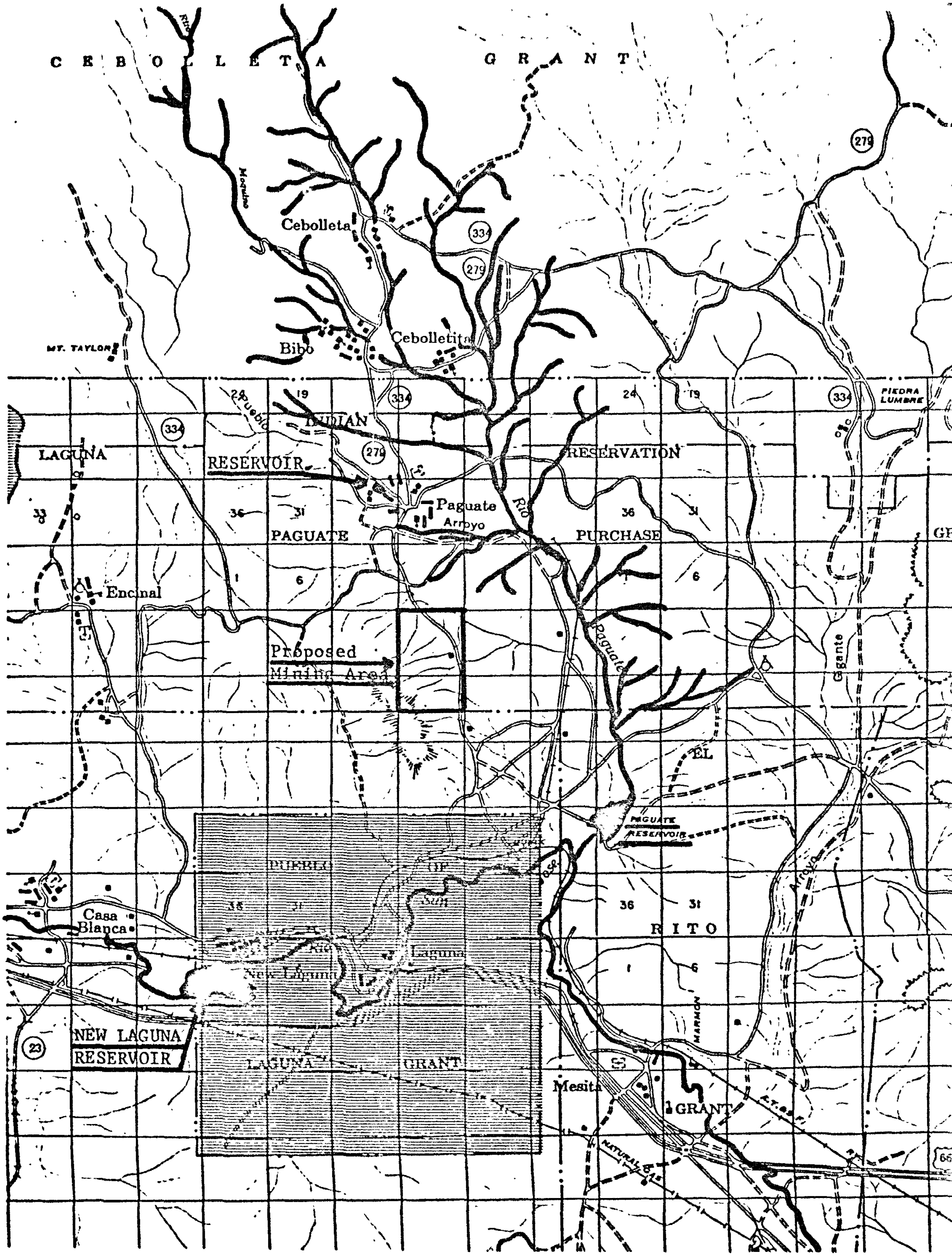
MAP D

Project Area Topographic Map
(USGS 7.5 Minute Series, Laguna and Mesita Quadrangles)



MAP E.

Structural Elements in Northwestern New Mexico
(Hilpert, 1969, p. 27)



MAP F

Surface Water Sources
Scale: ½"=1 mile
(Bureau of Land Management Color Quad Map, 1975, Cubero ...

PHOTOGRAPHS

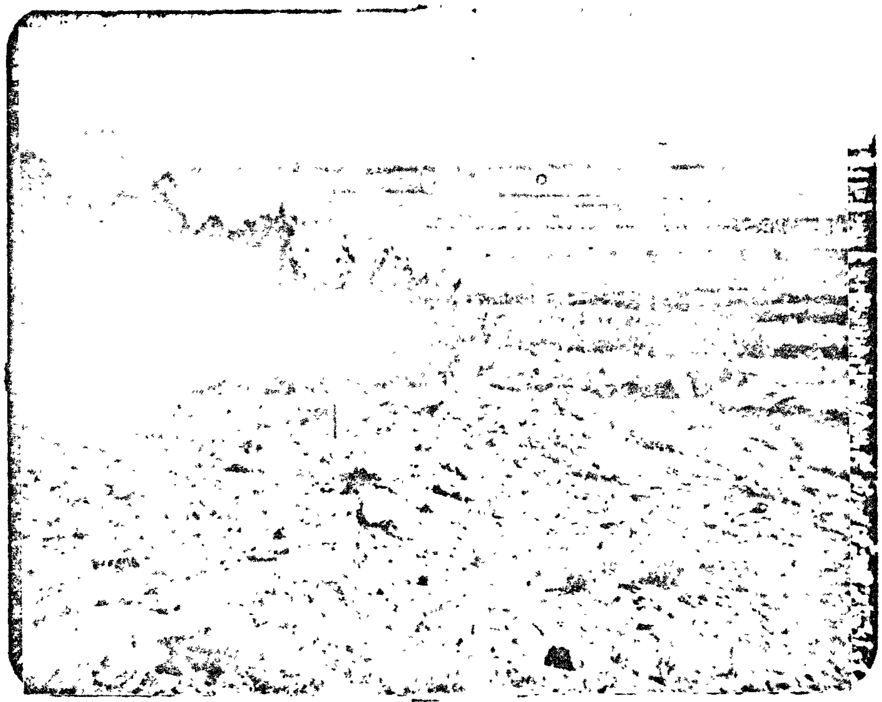


PHOTO A

Proposed location of P-15 shaft (stakes in center of picture) looking east; open-pit operations in background

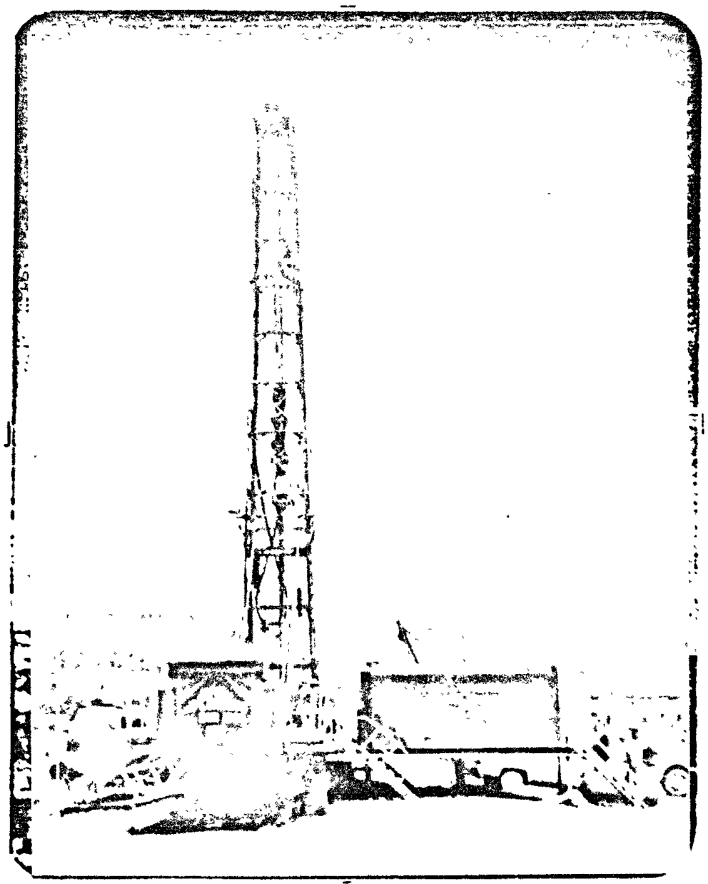


PHOTO B

Surface drilling of ventilation borehole for the P-10 Mine

[redacted]

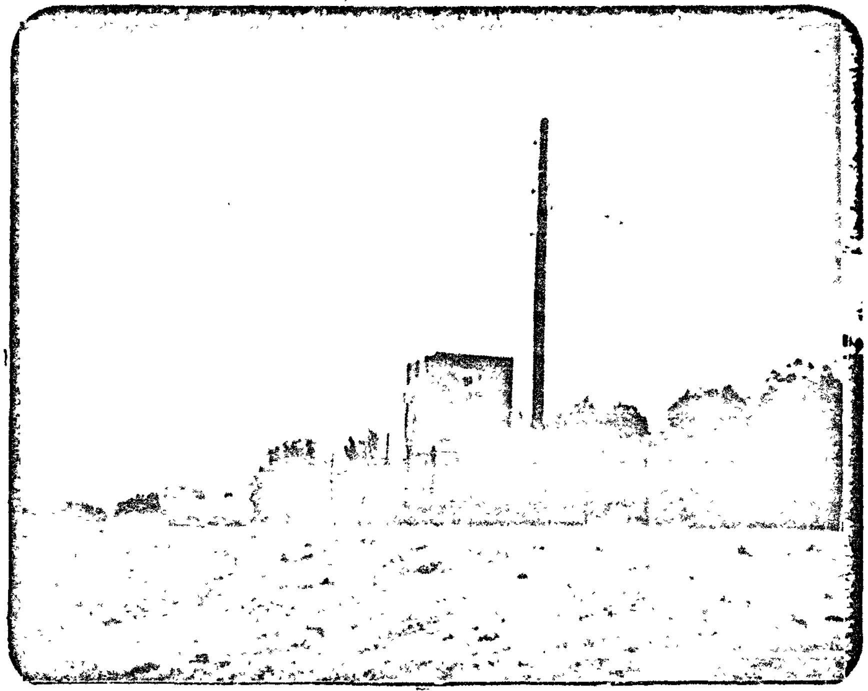


PHOTO C

PHOTO D

Surface fan and associated equipment for ventilation borehole for the P-10 Mine; white butane tanks are for heater

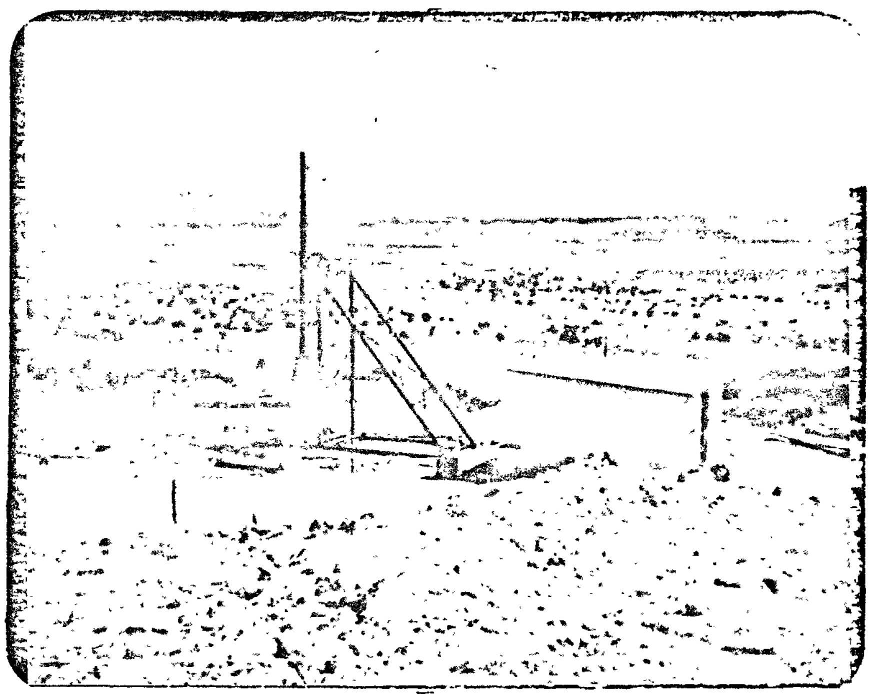


PHOTO E

Emergency hoisting equipment on ventilation borehole at the P-10 Mine; open-pit operations in the background

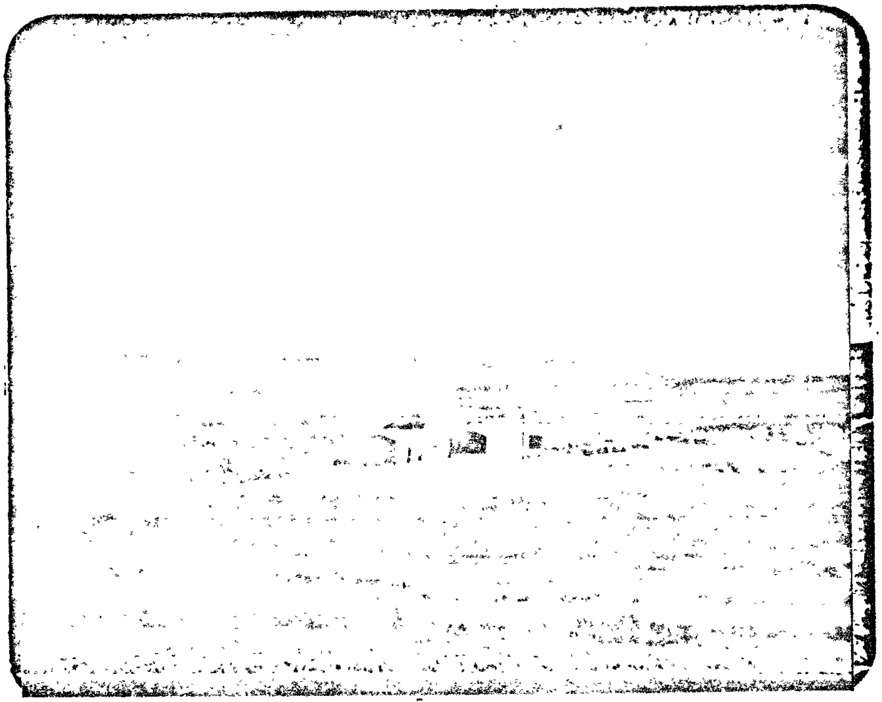


PHOTO F

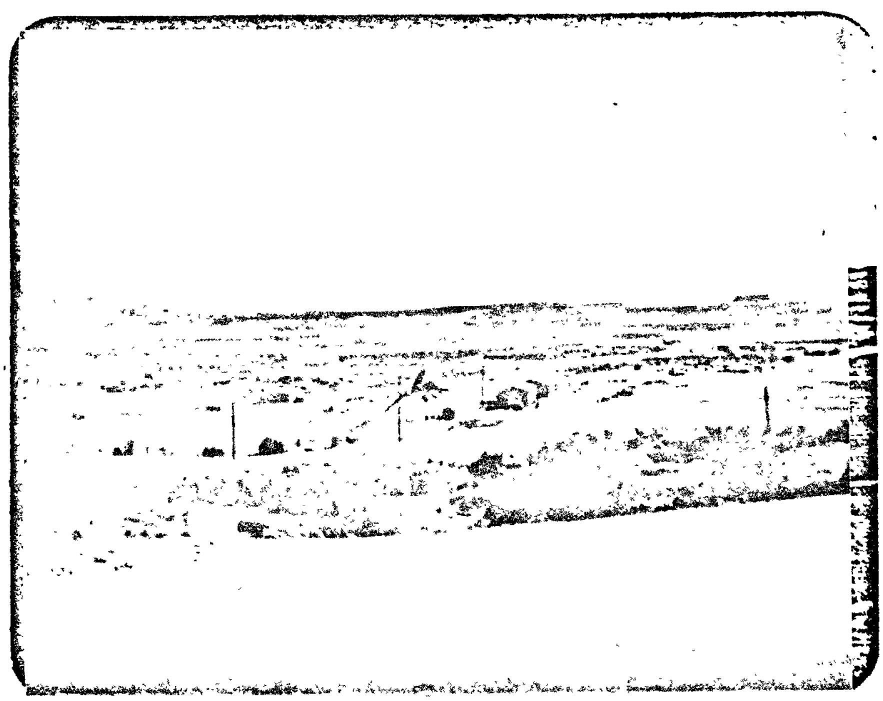


PHOTO G

Surface facilities for the P-10 Mine as seen from State Highway 279

PHOTO H

Proposed location of P-17 shaft (stakes next to tree in left-center of photo) looking southeast

PHOTO I

Northeast flank of Black Rim Mesa looking slightly southwest

PHOTO J

PHOTO K

Terrain and vegetation in the proposed mining area on the northeast flank of Black Rim Mesa

APPENDICES

APPENDIX I

Geologist's Memorandum Report

United States Department of the Interior

GEOLOGICAL SURVEY

P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

March 19, 1976

Memorandum

To: Area Geologist, USGS,
Roswell, New Mexico

From: Area Mining Supervisor, USGS,
Carlsbad, New Mexico

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Mines on Laguna Tribal Lease No. 4

Please review the enclosed copy of the above plan (one volume with map pocket) and return with your report.

Dale C. Jones
Dale C. Jones
Mining Engineer
For Area Mining Supervisor

DCJ:nb

Enclosure:

United States Department of the Interior
GEOLOGICAL SURVEY
P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

May 21, 1976

Memorandum

To: Area Geologist, SRMA, USGS, Roswell, New Mexico

From: Area Mining Supervisor, SRMA, USGS, Carlsbad

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Uranium Mines on Laguna Tribal Lease 4

Copies of the company's addendums to the subject plan are enclosed for your review and reference in preparing a geologic report for the plan. Please return the plan and addendums with your report.

Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:cj

Enclosures

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JUN 2 1976
U. S. Geological Survey
Carlsbad, N.M.

ac

United States Department of the Interior

GEOLOGICAL SURVEY
Drawer 1857
Roswell, New Mexico 88201

June 1, 1976

MEMORANDUM

TO: Area Mining Supervisor, Southern Rocky Mountain Area, Carlsbad, New Mexico

FROM: Pete C. Aguilar, Staff Geologist, Southern Rocky Mountain Area, Roswell, New Mexico

SUBJECT: Geologic review of Mining and Reclamation Plans for Anaconda's P-15 and P-17 uranium mines -- Jackpile-Paguate minesite, Valencia County, New Mexico

The Anaconda Company Uranium Division has submitted mining and reclamation plans pertinent to the development of two new uranium mines P-15 and P-17 in T. 10 N., R. 5 W.

Dale Jones is to be commended for efforts to secure geologic information to add to the original mining and reclamation plans for P-15 and P-17. The proponents of these mining plans do not incorporate appreciable geologic information into their mining plans. Two maps submitted for each minesite are without location markings (township and range etc.). The two stratigraphic columns submitted in addendum do not show location nor are they keyed to the maps previously submitted.

In response to questions asked, the proponent stated the following: (1) foresees no geologic hazards; (2) knows of no recognizable geological structures; (3) Paguate and Jackpile deposits are essentially the same; (4) the ore occurs in tabular lenses with irregular planar outlines and dimensions; (5) lenses vary in thickness from just a few feet to about 20 feet; (6) occassionally are stacked and (7) finds no other minerals.

Pete C. Aguilar
Pete C. Aguilar

NOTED
D. M. VAN SICKLE

AMERICAN REVOLUTION BICENTENNIAL
1776-1976

APPENDIX II

Stratigraphy

Table 1
(NMEI, 1975, p. 160)

REGIONAL STRATIGRAPHY (unconformities not shown)

Period	Epoch	Stratigraphic Unit
Quaternary	Recent and Pleistocene	San Juan Basin unnamed gravels and alluvium
Tertiary	Pliocene	Chuska Sandstone (700-900) and unnamed fluvial and lacustrine beds
	Eocene	San Juan Fm. (0-3000)
	Paleocene	Nacimiento Fm. (600-1000)
Cretaceous	Late	Ojo Alamo Sandstone (0-400) Kirtland Shale (0-1200) Fruitland Fm. (0-500) Pictured Cliffs Sandstone (70-400) Lewis Shale (0-2000) Mesaverde Group Cliff House Sandstone (100-1000) Menefee Fm. (0-2000) Point Lookout Sandstone (250-350) Crevasse Canyon Fm. (500-750) Gallup Sandstone (0-250) Mancos Shale (300-2000) Dakota Sandstone (0-200), possibly some Early Cretaceous
Jurassic	Late	Morrison Fm. Brushy Basin Member (0-600) Westwater Canyon Member (0-300) Recapture Member (0-500) San Rafael Group Cow Springs Sandstone (Bluff Sandstone) (0-350) Summerville Fm. (50-225) Todilto Limestone (0-100) Entrada Sandstone (0-300)
Triassic	Late	Wingate Sandstone (0-65) Chinle Fm. (0-1600)
	Middle (?) Early	Moenkopi (?) Fm. (0-200)
Permian		San Andres Limestone (0-125) Glorieta Sandstone (100-200) Yeso Fm. (500-750) Madera Limestone
Precambrian		Igneous and metamorphic rocks

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U. S. Geological Survey
Carlsbad, N.M.

P-15 AREA - TYPICAL STRATIGRAPHIC SECTION

(The Anaconda Company, 1976)

0-20'	Colluvium, containing slump block basaltic material from remnants of Wheat Mountain to the west.
20-458'	Cretaceous, undifferentiated. Marine sandstones grading downward into shales. Sandstone units are capped by a few feet of fairly hard, silica cemented sandstone.
458-496'	Lower Cretaceous, Basal Dakota sandstone. Its base is a hard, fine-to-medium grained, sugary textured, rounded to sub-rounded sandstone (± 10') that grades abruptly upward into fairly soft carbonaceous and shaly siltstone. Lies unconformably on the Jurassic sediments.
496-600'	Jurassic, Jackpile sandstone member of Brushy Basin. Locally ± 100'. Generally gray to buff, medium grained, friable, massive sandstone. Quite kaolinitic, locally contains stringers, blebs and thin beds of gray-green mudstone. Mineralization in this area generally in the top third of the unit.
600-	Jurassic, Brushy Basin shale member. Generally near upper contact, calcareous green shales, mudstones and interbedded gray-green limestones, locally with recrystallized calcite.

P-17 AREA - TYPICAL STRATIGRAPHIC SECTION

(The Anaconda Company, 1976)

0-50'	Colluvium, containing blocks of basalt from remnants of Wheat Mountain to the west.
50-520'	Cretaceous, undifferentiated. Marine sandstones grading downward into shales. Sandstone units are capped by a few feet of fairly hard, silica and calcite cemented sandstone.
520-554'	Lower Cretaceous, Basal Dakota sandstone. Its base is a hard, fine-to-medium grained, sugary textured, rounded to sub-rounded sandstone (± 10') unit that grades abruptly upward into fairly soft carbonaceous and shaly siltstone. Lies unconformably on the Jurassic sediments.
554-648'	Jurassic, Jackpile sandstone member of Brushy Basin. Locally ± 95'. Generally gray to buff, medium grained, friable, massive sandstone. Quite kaolinitic, locally contain stringers, blebs and thin beds of gray-green mudstone. Near the base of the section the mudstones are intimately mixed with the sandstone, making selection of the Brushy Basin contact difficult. Mineralization in this area generally in the top third of the unit.
648-	Jurassic, Brushy Basin shale member. Generally near upper contact, calcareous green shales, mudstones and interbedded gray-green limestone, locally with recrystallized calcite.

APPENDIX III

Seismic Data

Figure 1

Locations of felt earthquakes and instrumental epicenters within 60 miles of Mariano Lake. Numbers correspond to event numbers in Tables 1 and 2 (NMEI, 1975, p. 171).

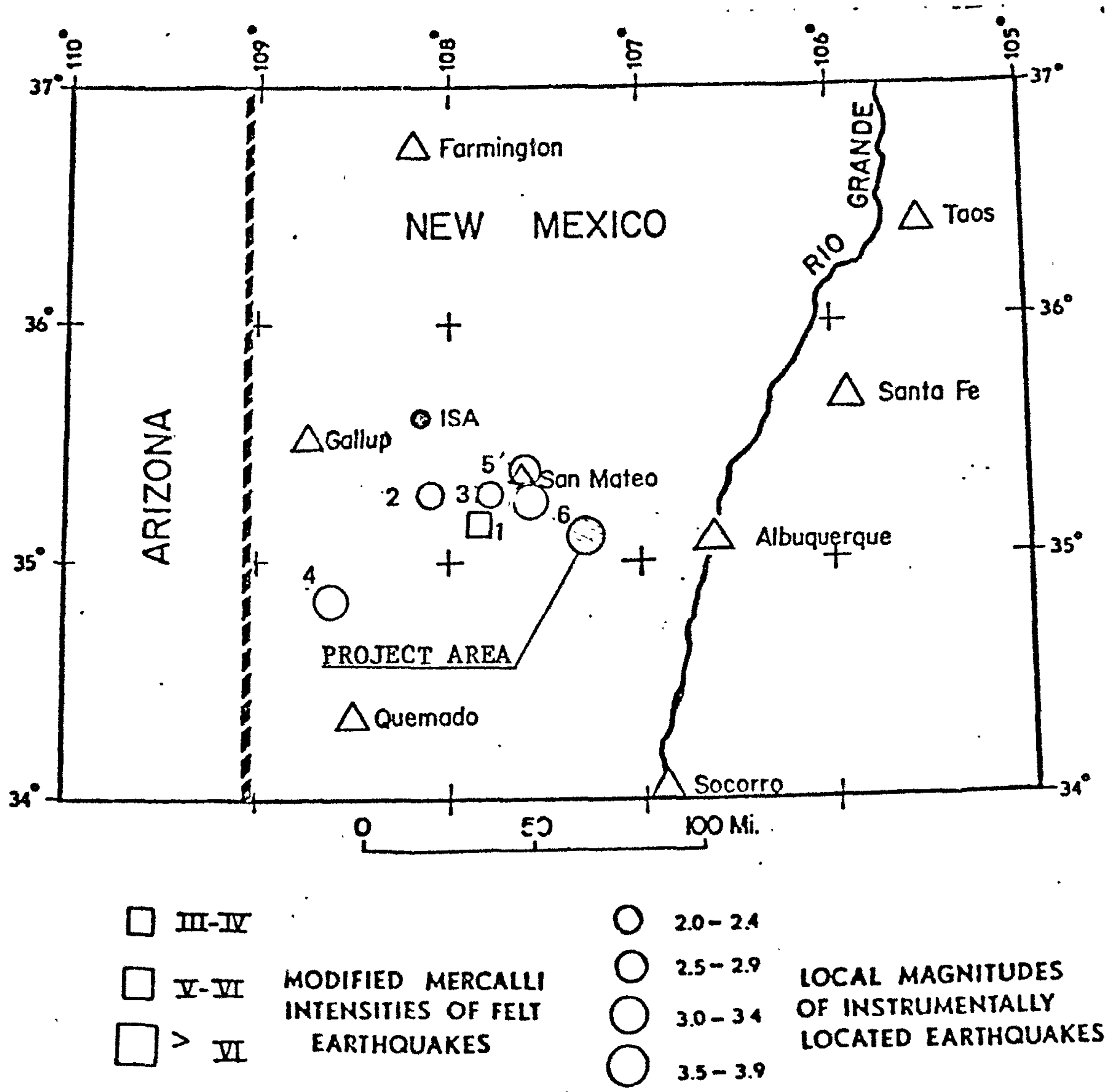


Table 1

Earthquakes felt within 60 miles of Mariano Lake prior to 1962 (NMEI, 1975, p. 170).

No.Δ	Yr	Mo	Day	Time GMT+	Location of Max. Reported Intensity	Maximum Reported Intensity†
1	1940	May	17	05.10	Grants	(III)

* From U. S. Dept. of Commerce, NOAA, ERD U. S. Earthquakes. Prepared annually, it lists epicenters and associated phenomena of all earthquakes recorded or reported in the United States.

Δ Number corresponds to earthquake location number shown in Figure 5-6.

\+ Greenwich Mean Time

† Modified Mercalli Intensity Scale of 1931 (see Appendix D).

Table 2

Instrumentally located earthquakes within 60 miles of Mariano Lake January 1962, through April 1974 (NMEI, 1975, p. 173).

No.†	Date Yr Mo Day	Origin Time GMT*	Location Lat°N	Location Long°W	Magnitude** m_b	Magnitude** M_L	References+
2	1963 Aug. 21	00:23:21.2	35.3	108.1		2.0	(1)
3	1963 Aug. 27	05:18:17.0	35.3	107.8		2.3	(1)
4	1969 Aug. 23	21:41:54.2	34.8	108.7		3.0	(3)
5	1971 May 22	22:31:19.8	35.4	107.6		2.8	(3)
6	1973 Dec. 24	02:20:14.9	35.3	107.7	4.4	4.1	(2)

† Numbers correspond to earthquake location numbers shown in Figure 5-6.

* Greenwich Mean Time.

** m_b is reported by U. S. G. S. (Earthquake Data Report); M_L was calculated by New Mexico Institute of Mining and Technology, Socorro, New Mexico, using seismograms from stations at Albuquerque and Socorro.

\+ Numbers in this column refer to the following sources:
(1) Sanford, 1965; (2) U. S. Dept. of Interior, USGS, ERL; (3) Toppozada and Sanford, 1972.

Figure 2

Locations of fe't earthquakes and instrumental epicenters in the vicinity of Mount Taylor. Numbers correspond to event numbers in Tables 3 and 4 (NMEI, 1974, p. 87).

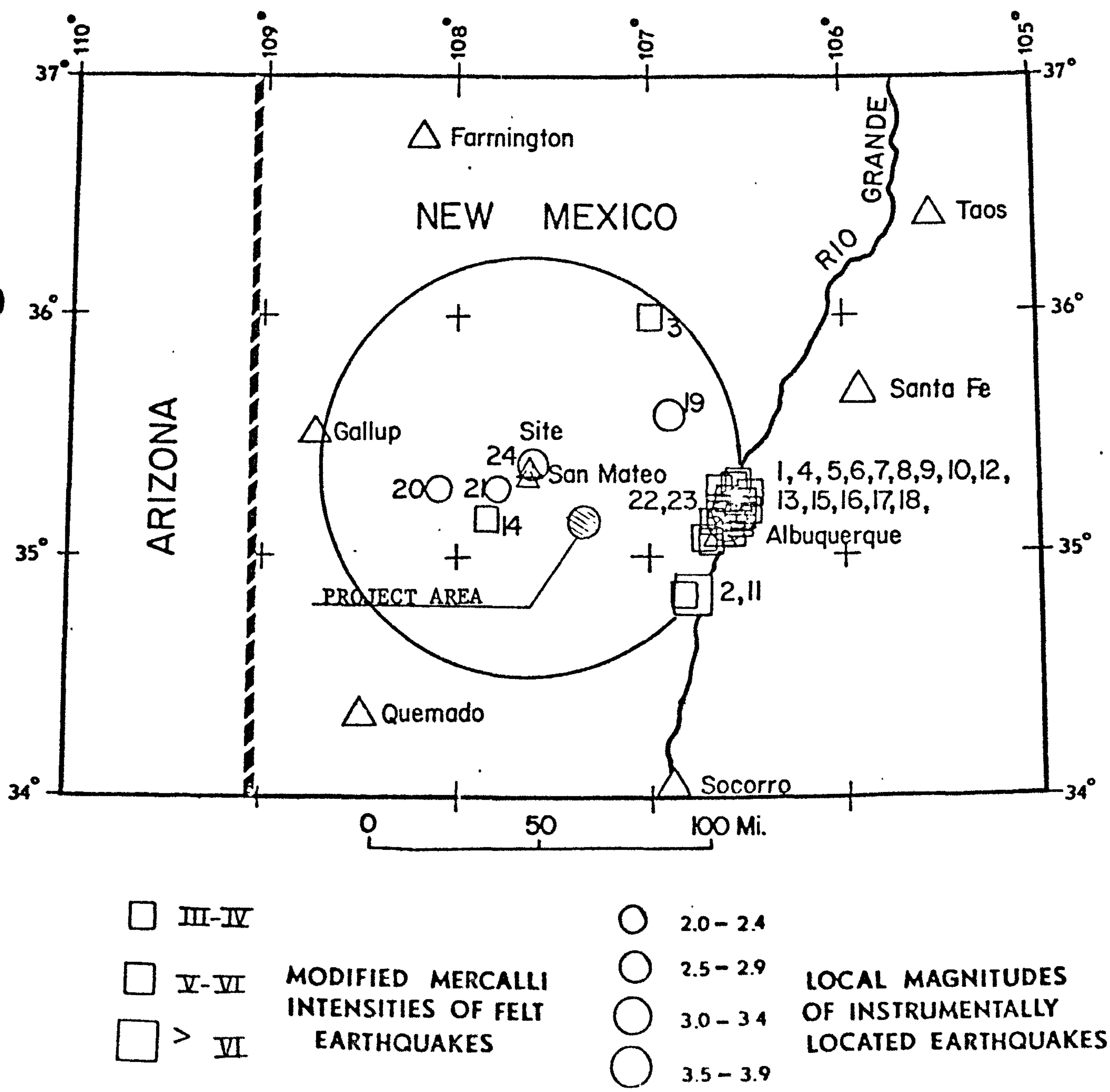


Table 3

Earthquakes felt in the vicinity of Mount Taylor prior to 1962 (NMEI, 1974, p. 88).

No.	Yr Mo Day	Time GMT[▼]	Location of Max. Reported Intensity	Maximum Reported Intensity*	References[+]	Remarks
1	1893 July 12	13:00 to 14:00	Albuquerque	V	(1),(2)	Three shocks.
2	1893 Sept. 7		Los Lunas	VII	(1),(2)	Strongest shock of a 3 month long swarm.
3	1921 July 31	03:55	Senorito	IV	(2)	
4	1930 Mar. 23	19:00	Albuquerque	(III-IV)	(3)	
5	1930 Dec. 3	21:36	Albuquerque	(IV)	(3)	Two distinct shocks.
6	1930 Dec. 4	22:30	Albuquerque	(III)	(3)	Aftershock of Dec. 3.
7	1931 Jan. 27		Albuquerque	(III)	(3)	
8	1931 Feb. 3	23:45	Albuquerque	V	(4)	
9	1931 Feb. 5	04:48	Albuquerque	VI	(3)	Hundreds left houses. Goods thrown from several stores, shelves.
10	1936 Sept. 9	12:55	Albuquerque	(III)	(3)	Two weak shocks.
11	1938 Mar. 23	06:00	Los Lunas	(III)	(3)	
12	1938 Apr. 15	21:00	Albuquerque	(III)	(3)	
13	1938 Apr. 16	08:15	Albuquerque	(III)	(3)	
14	1940 May 17	05.10	Grants	(III)	(3)	
15	1947 Nov. 6	16:50	San Antonito	(V-VI)	(3)	Felt in 10 mi. radius
16	1954 Nov. 2	17:00	Albuquerque	(IV)	(3)	Felt 20 mi. NS direction.
17	1954 Nov. 3	20:39	Albuquerque	V	(3)	Felt 20 mi. NS direction.
18	1956 Apr. 26	03:30	Sandia Mtns.	V	(3)	

▼Greenwich Mean Time.

*Modified Mercalli Intensity Scale of 1931 (see Appendix A). Intensity values assigned by the author are given in parentheses.

+Numbers given in this column are for the references from literature cited listed below: (1) Eppley, 1956; (2) Woollard, 1968; (3) U.S. Earthquakes (a U. S. Dept. of Commerce publication prepared annually that lists epicenters and associated phenomena of all earthquakes recorded or reported in the United States); (4) personal communications, S. A. Northrop, 1972.

Table 4

Instrumentally located earthquakes in the vicinity of Mount Taylor January 1962, through June 1971 (NMEI, 1974, p. 90).

No.	Date Yr Mo Day	Origin Time GMT[Ψ]	Location Lat °N	Long °W	Magnitude* m_b	M_L	References[+]
19	1962 June 14	07:27:55.8	35.6	106.9		2.8	(1)
20	1963 Aug. 21	00:23:21.2	35.3	108.1		2.0	(1)
21	1963 Aug. 27	05:18:17.0	35.3	107.8		2.3	(1)
22	1970 Nov. 28	07:40:11.6	35.0	106.7	4.5	3.5	(2)
23	1971 Jan. 4	07:39:06.7	35.0	106.7	4.7	3.8	(2)
24	1971 May 22	22:31:19.8	35.4	107.6		2.8	(3)

[Ψ] Greenwich Mountain Time.

*m_b is reported by U.S. Dept. Commerce (Earthquake Data Report); M_L was calculated by New Mexico Institute Mining and Technology, Socorro, New Mexico, using seismograms from stations at Albuquerque and Socorro.

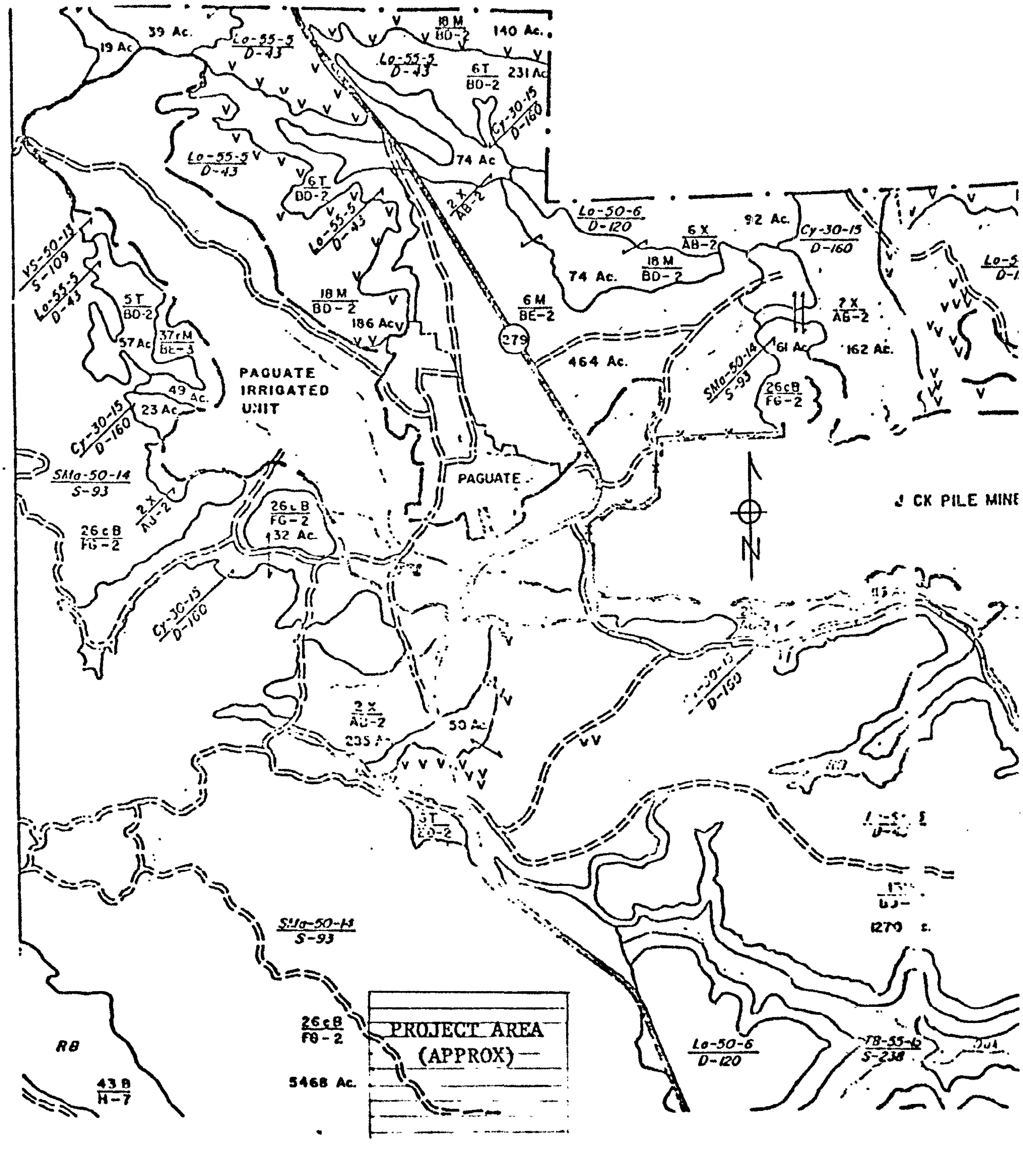
[+] Numbers in this column are for the references from literature cited listed below: (1) Sanford, 1965; (2) U.S. Dept. of Commerce, Earthquake Data Report, ERL; (3) Toppozada and Sanford, 1972.

APPENDIX IV

Soils in the Vicinity of the Jackpile-Paguate Mine

Soils in the Vicinity of Jackpile-Paguate Mine

(The Anaconda Company, 1976)



18M
BD-2 Soil Designation (Refer to Table 2.1-1)

-- Extent of Mine Disturbance at Time of Soil Mapping

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Carlsbad, N. M.

TABLE 2.1-1

MAP SYMBOLS AND DESCRIPTION
FOR SOILS APPEARING ON PLATE 2.1-1
(The Anaconda Company, 1976)

Map Symbol	Soil Description
2X / AB-2	A deep, fine textured, slowly permeable, moderately eroded soil formed from recently deposited alluvial soil materials of mixed origin, occurring on nearly level to gently sloping (0-3%) flood plains.
5T / BD-2	A deep, medium textured, slowly permeable, moderately eroded soil formed from outwash soil material of mixed origin moved and deposited by flood waters from higher slopes and occurs on gentle to strong (1-8%) slopes.
6T / BD-2	A deep, medium textured, moderately permeable, moderately eroded soil formed from soil material of mixed origin, moved and deposited by flood waters from higher slopes. This soil mapping unit is widely scattered within the Morrison geolgoical formation and is usually found below sandstone bluffs or ridges. It occurs on gentle to strong (1-8%) slopes.
6M / BE-2	A deep, medium textured, moderately permeable, moderately eroded soil formed from sandstone. It occurs on gentle to slightly steep (1-12%) slopes. This mapping unit is found in the Morrison, Chinle, and Mancos shale geological formation. It occupies approximately one-half of the mesa top north of Bell Rock and is associated with the Tres Hermanos sandstone formation.
10M / BD-3	A deep, coarse textured, moderately permeable, severely eroded soil developed from sandstone, and occurring on gentle to strong (1-8%) slopes. This soil mapping unit is of major importance and was found within the Morrison and Mancos shale geological formation.
10T / BD-3	A deep, coarse textured, moderately permeable, severely eroded soil formed from outwash soil material of mixed origin, moved and deposited by flood waters from higher slopes. This soil occurs on gentle to strong (1-8%) slopes. This soil mapping unit is of major importance and occurs primarily within the Morrison geological formation.

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TABLE 2.1-1 (Cont'd)

Map Symbol	Soil Description
18M / BD-2	A moderately deep, medium textured, moderately permeable, moderately eroded soil developed from sandstone and found commonly on mesa tops. It occurs on gentle to strong (1-8%) slopes.
26cB / FG-2	A shallow, fine textured, slowly permeable, moderately eroded soil developed from basic igneous (basalt) rock. It occurs on moderately steep to steep (12-55%) slopes.
30M / BE-3	A shallow, medium textured, moderately permeable, severely eroded soil developed from sandstone and occurring on gentle to slightly steep (1-12%) slopes.
37rM / BE-3	A very shallow, medium textured, severely eroded soil which is commonly found on gentle to slightly steep (1-12%) slopes. This mapping unit consists of very shallow sandstone soils with bedrock usually occurring between 4 and 10 inches and is most frequently found near the rim of mesas. Exposed outcroppings of sandstone bedrock are common and may occupy as much as one-third of the area delineated.
43M / H-7	This mapping unit normally occurs as vertical sandstone bluffs on the rims of large mesas. It can be generally described as a miscellaneous land type. It is characteristic of the unit to have very steep (55%+) slopes, to have miscalleanous textures, and variable soil depths with undifferentiated erosion. It has sufficient usable soil material to provide some cover and forage for wildlife. Extensive areas of exposed sandstone bedrock and large boulders are common.

APPENDIX V

Meteorological Data

Figure 1

Average annual precipitation patterns over New Mexico. Isohyet interval is 2 inches (NMEI, 1974, p. 96).

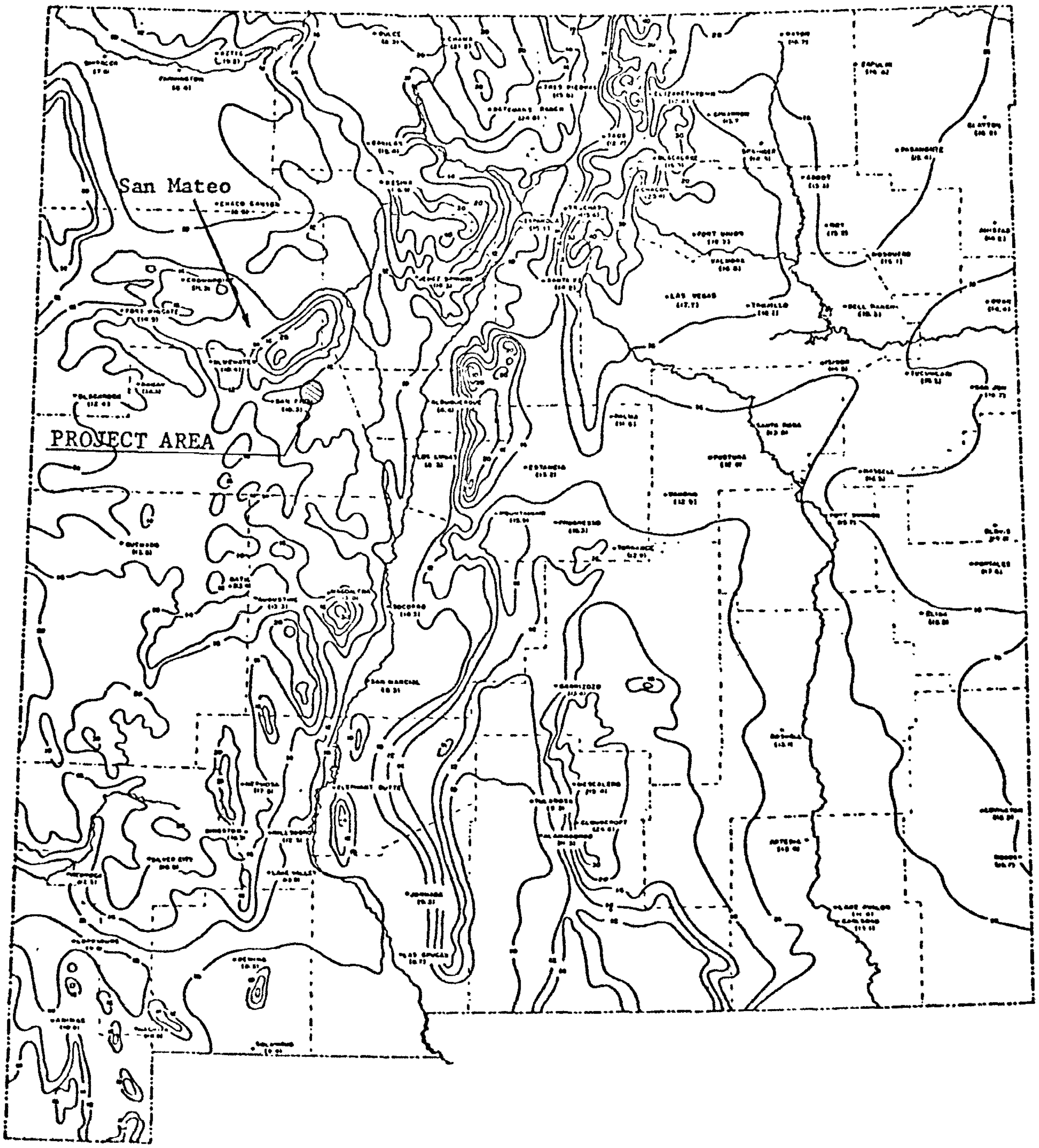


Table 1

Mean precipitation (inches) for stations in the Mount Taylor area (NMEI, 1974, p. 36).

Month	San Mateo* (7250 ft elev.) 1966-1973	San Mateo* (7250 ft elev.) Sept. 1972-Aug. 1973	Grants+ (6480 ft elev.) 1946-1960	San Fidel Ψ (6160 ft elev.) 1920-1954
Jan.	0.07	0.11	0.36	0.37
Feb.	0.09	0.12	0.39	0.46
Mar.	0.16	0.24	0.45	0.44
Apr.	0.16	0.09	0.36	0.65
May	0.36	0.36	0.43	0.79
June	0.75	1.19	0.69	0.79
July	1.98	2.83	1.81	1.65
Aug.	2.39	1.35	2.18	2.02
Sept.	1.31	1.81	1.17	1.43
Oct.	0.89	3.00	1.07	0.61
Nov.	0.24	0.12	0.33	0.41
Dec.	0.41	0.16	0.62	0.47
Annual	8.81	11.38	10.04	10.09

*Source: U.S. Dept. of Commerce, Environmental Data Service, NOAA, 1973.

+Source: U.S. Forest Service, 1973.

ΨSource: U.S. Dept. of Commerce, Weather Bureau, 1959.

Table 2

Four year summary of wind directions and speed at the Langmuir Laboratory, Socorro, New Mexico (NMEI, 1974, p. 44).

Season	Mean Direction	Mean Speed (mph)
Spring	West-southwest	8
Summer	South-southwest	6
Fall	Southwest	9
Winter	West-northwest	11

APPENDIX VI

Air Quality Regulations, Standards, and Data

STATE OF NEW MEXICO
Environmental Improvement Agency
HEALTH SAFETY WELLBEING COMFORT
P.O. Box 2348, Santa Fe, New Mexico 87503

AIR QUALITY DIVISION

RECEIVED
JUN 1 1976
U. S. Geological Survey
Carlsbad, N.M.

May 26, 1976

Mr. Dale Jones
USGS
Conservation Division
P.O. Box 1716
Carlsbad, New Mexico 88220

Dear Mr. Jones:

Enclosed is the data you requested for the Grants, New Mexico area. If you have any questions, or require any other assistance please feel free to contact me at 827-5271—extention 359 in Santa Fe.

Sincerely,

Martin J. Rinaldi
Program Manager
Monitoring and Surveillance Section

MJR:elc
Enclosure

deral Regul...

dix A—Reference Method for the Determination of Sulfur Dioxide in the Atmosphere (Pararosaniline Method).
dix B—Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method).
dix C—Reference Method for the Continuous Measurement of Carbon monoxide in the Atmosphere (Nondispersive Infrared Spectrometry).
dix D—Reference Method for the Measurement of Photochemical Oxidants Corrected for Interferences Due to Nitrogen Oxide and Sulfur Dioxide.
dix E—Reference Method for the Determination of Hydrocarbons Corrected for Methane.
ndix F—Reference Method for the Determination of Nitrogen Dioxide (24-Hour Sampling Method).

THORITY: The provisions of this Part ssued under sec. 4, Public Law 91-604, 1970.

0.1 Definitions.

) As used in this part, all terms not ned herein shall have the meaning n them by the Act.

) "Act" means the Clean Air Act, as nded (Public Law 91-604; 84 Stat.).

) "Agency" means the Environmental Protection Agency.

) "Administrator" means the Administrator of the Environmental Protection Agency.

) "Ambient air" means that portion ne atmosphere, external to buildings, which the general public has access.

) "Reference method" means a hod of sampling and analyzing for air pollutant, as described in an appendix to this part.

g) "Equivalent method" means any hod of sampling and analyzing for air pollutant which can be demonstrated to the Administrator's satisfaction to have a consistent relationship to reference method.

10.2 Scope.

a) National primary and secondary bient air quality standards under section 109 of the Act are set forth in this t.

b) National primary ambient air ality standards define levels of air ality which the Administrator judges necessary, with an adequate margin safety, to protect the public health. tional secondary ambient air quality ndards define levels of air quality ich the Administrator judges necessary to protect the public welfare from y known or anticipated adverse effects a pollutant. Such standards are subject to revision, and additional primary d secondary standards may be promulgated as the Administrator deems necessary to protect the public health and lfare.

(c) The promulgation of national imary and secondary ambient air quality standards shall not be considered in y manner to allow significant deterioration of existing air quality in any portion of any State.

(d) The proposal, promulgation, or revision of national primary and secondary ambient air quality standards shall not prohibit any State from establishing ambient air quality standards for that State or any portion thereof which are more stringent than the national standards.

§ 410.3 Reference conditions.

All measurements of air quality are corrected to a reference temperature of 25° C. and to a reference pressure of 760 millimeters of mercury (1,013.2 millibars).

§ 410.4 National primary ambient air quality standards for sulfur oxides (sulfur dioxide).

The national primary ambient air quality standards for sulfur oxides, measured as sulfur dioxide by the reference method described in Appendix A to this part, or by an equivalent method, are:

(a) 80 micrograms per cubic meter (0.03 p.p.m.)—annual arithmetic mean.

(b) 365 micrograms per cubic meter (0.14 p.p.m.)—Maximum 24-hour concentration not to be exceeded more than once per year.

§ 410.5 National secondary ambient air quality standards for sulfur oxides (sulfur dioxide).

The national secondary ambient air quality standards for sulfur oxides, measured as sulfur dioxide by the reference method described in Appendix A to this part, or by an equivalent method, are:

(a) 60 micrograms per cubic meter (0.02 p.p.m.)—annual arithmetic mean.

(b) 260 micrograms per cubic meter (0.1 p.p.m.)—maximum 24-hour concentration not to be exceeded more than once per year, as a guide to be used in assessing implementation plans to achieve the annual standard.

(c) 1,300 micrograms per cubic meter (0.5 p.p.m.)—maximum 3-hour concentration not to be exceeded more than once per year.

§ 410.6 National primary ambient air quality standards for particulate matter.

The national primary ambient air quality standards for particulate matter, measured by the reference method described in Appendix B to this part, or by an equivalent method, are:

(a) 75 micrograms per cubic meter—annual geometric mean.

(b) 260 micrograms per cubic meter—maximum 24-hour concentration not to be exceeded more than once per year.

§ 410.7 National secondary ambient air quality standards for particulate matter.

The national secondary ambient air quality standards for particulate matter, measured by the reference method described in Appendix B to this part, or by an equivalent method, are:

(a) 60 micrograms per cubic meter—annual geometric mean, as a guide to be used in assessing implementation plans to achieve the 24-hour standard.

(b) 150 micrograms per cubic meter—maximum 24-hour concentration not to be exceeded more than once per year.

§ 410.8 National primary and secondary ambient air quality standards for carbon monoxide.

The national primary and secondary ambient air quality standards for carbon monoxide, measured by the reference method described in Appendix C to this part, or by an equivalent method, are:

(a) 10 milligrams per cubic meter (9 p.p.m.)—maximum 8-hour concentration not to be exceeded more than once per year.

(b) 40 milligrams per cubic meter (35 p.p.m.)—maximum 1-hour concentration not to be exceeded more than once per year.

§ 410.9 National primary and secondary ambient air quality standards for photochemical oxidants.

The national primary and secondary ambient air quality standard for photochemical oxidants, measured and corrected for interferences due to nitrogen oxides and sulfur dioxide by the reference method described in Appendix D to this part, or by an equivalent method, is: 160 micrograms per cubic meter (0.08 p.p.m.)—maximum 1-hour concentration not to be exceeded more than once per year.

§ 410.10 National primary and secondary ambient air quality standard for hydrocarbons.

The hydrocarbons standard is for use as a guide in devising implementation plans to achieve oxidant standards.

The national primary and secondary ambient air quality standard for hydrocarbons, measured and corrected for methane by the reference method described in Appendix E to this part, or by an equivalent method, is: 160 micrograms per cubic meter (0.24 p.p.m.)—maximum 3-hour concentration (6 to 9 a.m.) not to be exceeded more than once per year.

§ 410.11 National primary and secondary ambient air quality standard for nitrogen dioxide.

The national primary and secondary ambient air quality standard for nitrogen dioxide, measured by the reference method described in Appendix F to this part, or by an equivalent method, is: 100 micrograms per cubic meter (0.05 p.p.m.)—annual arithmetic mean.

APPENDIX A—REFERENCE METHOD FOR THE DETERMINATION OF SULFUR DIOXIDE IN THE ATMOSPHERE (PARAROSANILINE METHOD)

1. *Principle and Applicability.* 1.1 Sulfur dioxide is absorbed from air in a solution of potassium tetrachloromercurate (TCM). A dichlorosulfitomercurate complex, which resists oxidation by the oxygen in the air, is formed (*1, 2*). Once formed, this complex is stable to strong oxidants (e.g., ozone, oxides of nitrogen). The complex is reacted with pararosaniline and formaldehyde to form intensely colored pararosaniline methyl sulfonic acid (*3*). The absorbance of the solution is measured spectrophotometrically.

1.2 The method is applicable to the measurement of sulfur dioxide in ambient air using sampling periods up to 24 hours.

CONFIDENTIAL POL-EPA01-0000982

New Mexico Environmental Improvement Board
P.E.R.A. Building
P. O. Box 2348
Santa Fe, New Mexico 87501

RECEIVED
JUN 23 1975
U. S. Geological Survey
Carlsbad, N.M.

April 19, 1974

AIR QUALITY CONTROL REGULATION

Section Number 201 of the Ambient Air Quality Standards and Air Quality Control Regulations adopted by the New Mexico Health and Social Services Board on January 23, 1970, amended on June 26, 1971, and amended on June 16, 1973, is adopted to read:

"201. Ambient Air Quality Standards

A. The maximum allowable concentrations of total suspended particulate in the ambient air are as follows:

	Maximum Concentration
1. 24-hour average	150 $\mu g/m^3$
2. 7-day average	110 $\mu g/m^3$
3. 30-day average	90 $\mu g/m^3$
4. annual geometric mean	60 $\mu g/m^3$

B. When one or more of the following elements are present in the total suspended particulate, the maximum allowable concentrations of the elements involved, based on a thirty-day average, are as follows:

	Maximum Concentration
1. beryllium	0.01 $\mu g/m^3$
2. asbestos	0.01 $\mu g/m^3$
3. heavy metals (total combined)	10 $\mu g/m^3$

C. The maximum allowable concentrations of the following air contaminants in the ambient air are as follows:

	Maximum Concentration
1. sulfur dioxide	

(a) 24-hour average 0.10 ppm

(b) annual arithmetic average 0.02

2. hydrogen sulfide

(a) for the state, except the Pecos-Permian Basin Intrastate Air Quality Control Region (1-hour average)

0.003 ppm

(b) for the Pecos-Permian Basin Intrastate Air Quality Control Region (1/2-hour average)

0.100 ppm

(c) after January 1, 1976, for within corporate limits of municipalities within the Pecos-Permian Basin Intrastate Air Quality Control Region (1/2-hour average)

0.030 ppm

(d) after January 1, 1978, for within five miles of the corporate limits of municipalities having a population of greater than twenty thousand and within the Pecos-Permian Basin Intrastate Air Quality Control Region (1/2-hour average)

0.030 ppm

3. total reduced sulfur

(a) for the state, except the Pecos-Permian Basin Intrastate Air Quality Control Region including hydrogen sulfide (1-hour average)

0.003 ppm

(b) for the Pecos-Permian Basin Intrastate Air Quality Control Region, except for hydrogen sulfide (1/2-hour average)

0.010 ppm

(c) after January 1, 1976, for within corporate limits of municipalities within the Pecos-Permian Basin Intrastate Air Quality Control Region, except for hydrogen sulfide (1/2-hour average)

0.003 ppm

(d) after January 1, 1978, for within five miles of the corporate limits of municipalities having a population of greater than twenty thousand and within the Pecos-Permian Basin Intrastate Air Quality Control Region, except for hydrogen sulfide (1/2-hour average)

0.003 ppm

		Maximum Concentration
4.	carbon monoxide	
	(a) 8-hour average	8.7 ppm
	(b) 1-hour average	13.1 ppm
5.	nitrogen dioxide	
	(a) 24-hour average	0.10 ppm
	(b) annual arithmetic average	0.05 ppm
6.	photochemical oxidants (1-hour average)	0.06 ppm
7.	non-methane hydrocarbons (3-hour average)	0.19 ppm

D. On an annual average, the soiling index shall not exceed 0.4 cohs/1000 linear feet of air."

Adopted: 4-19-74

Filed: 5-3-74

Effective: 6-2-74

AIR QUALITY DATA REPORT

AGENCY STATE AGENCY   STATE NEW MEXICO   CITY PAGUATE -8D   SITE 003   YEAR 1975

POLLUTANT TOTAL SUSPENDED PART.   UNITS U GM/M3 (25DEG)   DATA FORMAT XXX.X

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	N	MEAN
01			41.5										1	41.5
02													0	
03		41.4											1	41.4
04								28.0					1	28.0
05		37.0				34.7							2	35.9
06													0	
07			68.9										1	68.9
08													0	
09									11.3				1	11.3
10								48.6					1	48.6
11		31.6				36.2	11.0						3	26.3
12				21.9									1	21.9
13	58.2												1	58.2
14													0	
15									28.3				1	28.3
16								19.5					1	19.5
17		21.5	150.8			43.4	30.3						4	61.5
18	35.5												1	35.5
19			74.8										1	74.8
20													0	
21								23.2	30.3				2	26.8
22													0	
23		54.0											1	54.0
24	33.0												1	33.0
25			60.7	55.6									2	58.2
26													0	
27									57.4				1	57.4
28													0	
29													0	
30													0	
31			43.5										1	43.5
N	3	5	6	2		3	2	4	4				29	
MN	42.2	37.1	73.4	38.8		38.1	20.7	29.8	31.8				29	42.5
MX	58.2	54.0	150.8	55.6		43.4	30.3	48.6	57.4				29	150.8

APPENDIX VII

Hydrologist's Memorandum Report

United States Department of the Interior

GEOLOGICAL SURVEY

P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

March 19, 1976

Memorandum

To: District Chief, WRD, USGS,
Albuquerque, New Mexico

From: Area Mining Supervisor, SRMA, USGS,
Carlsbad, New Mexico

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Mines on Laguna Tribal Lease No. 4

Please review the enclosed copy of the above plan (one volume with map pocket) and return with your report.

Dale C. Jones

Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:nb

Enclosure:

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : Area Mining Supervisor, SRMA, USGS, Carlsbad, NM DATE: March 26, 1976

FROM : District Chief, WRD, USGS, Albuquerque, NM

SUBJECT: Review of the Anaconda Company's proposed mining and reclamation plan for the P-15 and P-17 mines on Laguna Tribal lease No. 4

I have reviewed the above mining plan and agree that the stated impacts of these two underground mines on water resources will be relatively minor for the reasons stated. In other parts of New Mexico where mine dewatering is a problem, the mines are several hundred feet below the water table. In this area mining will be done at or just below the water table, so yields from the relatively impermeable material will be low and drawdown will be small.

Although the discharges will probably be low, the 1.28 and 1.29 acre settling ponds for mine water may be too small. In this area annual evaporation is probably 6 feet or less from ponds, implying that, on the average, evaporation will consume about 5 gallons per minute from each of the two ponds. Perhaps provision should be made in the plan for discharges exceeding 5 gallons per minute. The ponds must have sufficient volume to contain winter discharges when evaporation rates are lower than 5 gallons per minute. Also, the ponds should be designed to minimize leakage, which could cause contamination of ground water in the area.

Forest P. Lyford

F. P. Lyford
Hydrologist

For: W. E. Hale
District Chief

RECEIVED
MAR 29 1976
U. S. Geological Survey
Carlsbad, N.M.

United States Department of the Interior

GEOLOGICAL SURVEY

P.O. BOX 1716

CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

May 21, 1976

Memorandum

To: District Chief, WRD, USGS, Albuquerque, New Mexico

From: Area Mining Supervisor, SRMA, USGS, Carlsbad, New Mexico

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Uranium Mines on Laguna Tribal Lease No. 4

Enclosed are copies of the subject plan, the company's addendums to the plan, and your original memorandum report on the plan dated March 26, 1976.

Please review the enclosed material to see if the addendums to the plan necessitate revision or addition to your original report. Please return the plan and addendums to this office.

Dale C. Jones
Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:cj

Enclosures

UNITED STATES GOVERNMENT

Memorandum

TO : Area Mining Supervisor, SRMH, USGS, Carlsbad, NM

DATE: May 26, 1976

FROM : District Chief, WRD, USGS, Albuquerque, NM

SUBJECT: Addendums to the Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Uranium Mines.

I have reviewed the addendums to Anaconda Company's Proposed Mining and Reclamation Plan and have only a couple of comments. First, the pumping rate at 183 gpm from the P-10 mine reported in the letter dated April 14, 1976, does not agree with the pumping rate reported in the letter dated April 21, 1976, which averaged about 30 gpm as calculated from the total water pumped. Second, reference was made to our water resources study on the Pueblo of Laguna. We have water quality data in the form of miscellaneous chemical analyses and specific conductance measurements for both Paguate Reservoir and the other, which is called New Laguna Reservoir. This can probably be supplied upon written consent from the Laguna Governor. Both reservoirs are nonfunctioning because of sediment filling.

Enclosed is the mining plan with addendums.

Forest P. Lyford

F. P. Lyford
Hydrologist

For: W. E. Hale
District Chief

Encl.

RECEIVED
MAY 27 1976
U. S. Geological Survey
Carlsbad, N.M.

APPENDIX VIII

Water Quality Data

Table 1

Analytical Data for Surface Water Sampling
(EPA, 1975, p. 33)

Station Description	Number of Samples	Gross Alpha (pCi/l)			Radium-226 (pCi/l)			Uranium (mg/l)			Selenium (mg/l)			Vanadium (mg/l)		
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
Rio Paguate at Paguate	1	-	-	2.8	-	-	0.11	-	-	<0.02	-	-	<0.01	-	-	0.6
Rio Moquino upstream of Jackpile Mine	1	-	-	11.2	-	-	0.17	-	-	<0.02	-	-	<0.01	-	-	1.8
Rio Paguate at Jackpile Ford	1	-	-	270	-	-	4.8	-	-	1.2	-	-	<0.05	-	-	0.5
Rio Paguate at Paguate Reservoir Discharge	1	-	-	230	-	-	1.94	-	-	1.1	-	-	<0.01	-	-	0.6
Rio San Jose at Interstate Bridge	1	-	-	38	-	-	0.37	-	-	0.10	-	-	<0.01	-	-	0.3

ALKALINITY

Alkalinity in drinking water should be sufficient to enable floc formation during coagulation, but not so high as to cause physiological distress in humans. A chemically balanced water, neither corrosive nor encrusting, should be maintained. Alkalinity should not be less than 30 mg/l nor more than 500 mg/l (3).

ARSENIC

The use of inorganic arsenic in insecticides necessitates the need for a limit on the concentration of arsenic in drinking water supplies. A considerable proportion is retained by the body at low intake levels (2). The United States Public Health Service Drinking Water Standards of 1962 set concentration limit not to exeed 0.01 mg/l.

BARIUM

Barium is considered a general muscle stimulant, especially the heart muscle (2). The fatal dose for man is 550-600 mg. Concentrations of barium have been set by the United States Public Health Service Drinking Water Standards of 1962 at 1.0 mg/l because of the toxic effect on the heart, blood vessels, and nerves.

BICARBONATE

Bicarbonate is a universal constituent of natural waters. Bicarbonate has not been considered as a health hazard. However, some reports indicate that concentrations in excess of 700 mg/l may be harmful to some persons. Bicarbonate is an essential constituent in water as it provides a buffering capacity to the water.

BORON

The ingestion of large amounts of boron can affect the central nervous system and protracted ingestion may result in a clinical syndrome known as borism. Boron is an essential element to plant growth, but is toxic to many plants at levels as low as 1 mg/l. The United States Public Health Service has established a limit of 1 mg/l which provides a good factor of safety physiologically and also considers the domestic use of water for home gardening (3).

CADMIUM

Cadmium is believed to be a nonessential, nonbeneficial element biologically. Cadmium also has a high toxic potential. Minute amounts are known to interfere with metabolism and cause arterial changes in man. Because of this, the United States Public Health Service Drinking Water Standards of 1962 set the allowable concentration of cadmium at 0.01 mg/l.

CALCIUM

Calcium salts and calcium ions are among the most commonly encountered substances in water. They may result from leaching of soil and other natural sources, or they may be contained in sewage and many types of industrial waste. The United States Public Health Service Drinking Water Standards do not carry any limit for calcium. The World Health Organization International Standards of 1958 indicates 75 mg/l is a permissible limit and 200 mg/l is an excessive limit in drinking water.

CARBONATE

Carbonate is directly related to bicarbonate and the concentration of each varies with the pH. The United States Public Health Service Drinking Water Standards of 1962 place no restrictions on carbonates in natural waters, nor in chemically treated waters, as was done in the 1946 standards. Concentration in excess of 350 mg of carbonate should not be allowed in drinking water because it may be harmful to some people.

CHLORIDE

Chlorides in drinking water are generally not harmful to human beings until high concentrations are reached, although chlorides may be harmful to some people suffering from diseases of the heart or kidneys. Restrictions on chloride concentrations are generally based on palatability requirements rather than health. A concentration exceeding 250 mg/l is not recommended.

CHROMIUM

The relationship or effect of chromium on the human body is not known. Chromium is not known to be a common element of food sources. That which may be found usually arises from cooking in stainless steel pots. The United States Public Health Service Drinking Water Standards of 1946 set as the allowable concentration of chromium at 0.05 mg/l based on the lowest amount analytically determinable at the time the standard was established.

COLOR AND ODOR

Color and odor requirements are easily attained in properly designed and operated treatment plants. When the requirements are not met, it is an indication of inadequate facilities or operation of the system. The United States Public Health Service Drinking Water Standards set the limit of color at 15 units and odor at 3 units. These values do not reflect the safety of the water but rather the consumer acceptance.

CONDUCTANCE

Conductivity is the reciprocal of electrical resistance in ohms of a column of solution one centimeter long with a cross section of one square centimeter at a specific temperature. The greater the concentration of dissolved ionic constituents in water, the less its resistance to current flow. Thus, conductivity serves as a measure of the total dissolved solids in the water. Salt concentrations may rise to levels harmful to living organisms because of the increase in osmotic pressure. Conductance should be below 1,000 micromhos at 25°C for good drinking water quality.

COPPER

Copper is an essential and beneficial element in human

metabolism. A deficiency in copper results in nutritional anemia in infants. The daily requirement for adults has been estimated at 2.0 mg. Higher concentrations of copper impart an undesirable taste to drinking water. Because of this, the United States Public Health Service Drinking Water Standards ~~raised~~ the recommended level from ~~0.2~~ mg/l in 1946 to ~~3.0~~ mg/l in 1962.
3.0 1.0

CYANIDE

Cyanide standards are based on the toxicity for fish and not for man. Lethal toxic effects occur only when the detoxifying mechanism of the body (conversion to thiocyanate) is overburdened. The United States Public Health Service Drinking Water Standards set the recommended limit of 0.01 mg/l.

FLUORIDE

There are numerous articles describing the effect of fluoride-bearing water on the dental enamel of children. These papers indicate that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled teeth in children, and for adults concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. There is evidence to support the contention that fluorides in excess of the threshold for mottling teeth, and up to 5 mg/l, produce no harmful effects other than mottling.

The United States Public Health Service Drinking Water Standards of 1962 set a limit on fluorides at twice the optimum level shown in the following table. Recommended levels are based on an average of maximum daily air temperatures in accordance with the following table. It is reasoned that children drink more water in warm climates; hence, fluoride content in the water should be lower to prevent excessive total fluoride consumption.

TABLE

ANNUAL AVERAGE OF MAXIMUM DAILY AIR TEMPERATURES °F			RECOMMENDED CONTROL LIMITS OF FLUORIDE AND mg/l		
			LOWER	OPTIMUM	UPPER
50.0	–	53.7	0.9	1.2	1.7
53.8	–	58.3	0.8	1.1	1.5
58.4	–	63.8	0.8	1.0	1.3
63.9	–	70.6	0.7	0.9	1.2
70.7	–	79.2	0.7	0.8	1.0
79.3	–	90.5	0.6	0.7	0.8

GROSS BETA, RADIUM 226, STRONTIUM

The United States Public Health Service Drinking Water Standards set a limit of 3 *uuc* per liter and 10 *uuc* per liter for radium 226 and strontium 90 respectively. The standards set as an upper limit of gross beta activity at 1,000 *uuc* per liter in the absence of strontium 90 and alpha emitters.

HARDNESS

Hardness over 100 mg/l as $CaCo_3$ becomes increasingly [illegible]ient because it results in waste of soap and encrustation on utensils. The major detrimental effect of hardness is economic. For this reason the 1962 United States Public Health Service Drinking Water Standards have not set health-related limits on this parameter; but, softening is recommended for waters with a hardness above 250 mg/l.

IRON

The 1962 United States Public Health Service Drinking Water Standards set the recommended limit for iron at 0.3 mg/l for aesthetic reasons, such as staining of fixtures and clothing. This limit is not based upon physiological considerations, for iron in trace amounts is essential for nutrition. The daily nutritional requirement is 1 to 2 mg, and most diets contain 7 to 35 mg per day. Consequently, drinking water containing iron is unpalatable and unaesthetic concentrations constitute a nuisance but have little effect on the total daily intake.

LEAD

Lead is very toxic if taken into the body by either brief or prolonged exposure. Lead is a cumulative poison. Lead is absorbed from food, air, water, and tobacco smoke. The United States Public Health Service Drinking Water Standards set the limit at 0.05 mg/l.

MAGNESIUM

Magnesium is an essential mineral element for human beings. The daily requirement for human beings is about 0.7 grams. Magnesium is considered relatively non-toxic to man and not a public health hazard. Before toxic conditions are reached in water the taste becomes quite unpleasant. At high concentration magnesium salts have a laxative effect, although the human body can develop a tolerance over a period of time. The 1946 United States Public Health Service Drinking Water Standards recommended a limit of 125 mg/l, but there is no limit in the 1962 standards.

MANGANESE

The 1962 United States Public Health Service Drinking Water Standards set the recommended limit for manganese at 0.05 mg/l. This requirement is the result of aesthetic considerations rather than any physiologic considerations.

Manganese is undesirable in domestic water supplies because it causes unpleasant tastes and stains, and fosters growth of some micro-organisms in reservoirs, filters, and distribution systems.

MERCURY

Mercury is found in seawater at a level of 0.00003 mg/l. It is found in marine plants at approximately 0.03 mg/l. Severe neurological disorders have been reported as a result of eating fish and shellfish from contaminated waters. For phytoplankton, the minimum lethal concentration of mercury salts has been reported to range from 0.9 to 60 mg/l of mercury. The toxic effects of mercury salts are accentuated by the presence of trace amounts of copper (3). The Technical Review Committee Tentative Standards have prepared in their revision of the Public Health Service Drinking Water Standards a maximum allowable unit of 0.005 mg/l mercury (4).

MOLYBDENUM

Molybdenum presents a particularly unique problem in irrigation waters in that ground waters frequently carry levels of the element that give rise to plant concentration toxic to cattle. In nutrient solution and soil solution measurements, 0.01 mg/l molybdenum in solution will produce legumes containing in the order of 5 mg/kg molybdenum or more in the tissue. This level is commonly accepted as the upper limit for safe feeding to cattle and it has been proposed as the tolerance limit. An upper limit of 0.05 mg/l has been proposed when the irrigation water is added to acid soils with a large capacity to combine with the element. The reason for this action is to protect against the possibility of inducing molybdenum toxicity at a later date as a result of overliming in humid and subhumid areas (3). The State has recommended a maximum allowable concentration of 0.01 mg/l for drinking water.

NICKEL

Nickel pollution is caused by industrial smoke and other wastes. It is very toxic to most plants but less to animals. Long-term studies with oysters found that a level of 0.121 mg/l nickel caused considerable mortality. Nickel toxicities occur in nature in conjunction with high levels of chromium in soils developed from serpentine rock. Growth of flax is depressed by the presence of 0.5 mg/l nickel and this value has been suggested for tentative tolerance limit in irrigation waters. Examination of more sensitive crops may suggest a lower value (3). The State has recommended a maximum allowable concentration of 0.05 mg/l for drinking water.

NITRATE

Until 1962, the United States Public Health Service Drinking Water Standards did not have a requirement for nitrates. At that time, however, a recommended limit of 45 mg/l for nitrates was established. This limit was established because of the relationship between high nitrates in water and infant methemoglobimenia.

pH

The pH of a water system was singled out by the early investigators of coagulation as the most important variable to be considered. The United States Public Health Service Drinking Water Standards recommend as the optimum a pH range of 6.0 to 8.5. Failure to operate within this range will result in chemical wasting and will [illegible]ected in the quality of the treated water.

PHOSPHATE

The limit for phosphorus concentrations in public water supplies has been considered, but it has not been established because of the complexity of the problem. The purpose of such limit would be twofold: (a) to avoid problems associated with algae and other aquatic plants and (b) to avoid coagulation problems due particularly to complex phosphates (3).

POTASSIUM

Potassium is one of the more common elements. It is an essential nutritional element. The 1962 United States Public Health Service Drinking Water Standards do not specify any limit for potassium. A dose of 1 to 2 grams of potassium is cathartic, and 1,000 to 2,000 mg/l is regarded as the extreme limit of potassium in drinking water (1).

SELENIUM

Before 1962, the presence of selenium in water was considered a matter of regional importance. It is now recognized as being toxic to both man and animals. The presence of selenium may cause an increase in dental caries in man and is a potential carcinogenic. In the 1946 release of the United States Public Health Service Drinking Water Standards the level of allowable selenium was 0.05 mg/l. Due to the seriousness of the effects, in 1962 the standards lowered the limit to 0.01 mg/l.

SILVER

Crystalline silver nitrate, $AgNO_3$, is sometimes used as a disinfectant in water supplies. Because of its skin and mucuous membrane discoloration along with pathological changes in the kidneys, liver, and spleen, the United States Public Health Service Drinking Water Standards have set the limit for silver at 0.05 mg/l.

SODIUM

Sodium salts are extremely soluble and are found in most natural waters. Sodium is the cation of many salts used in industry, and, as such, one of the most common ions in process wastes. Sodium in drinking water may be harmful to persons suffering from cardiac, renal, and circulatory diseases. The 1962 United States Public Health Service Drinking Water Standards do not establish a recommended level. However, it has been reported that levels of 200 mg/l may be injurious to some people.

SULFATE

The 1962 United States Public Health Service Drinking Water Standards recommend that sulfates do not exceed 250 mg/l. This limit does not appear to be based on taste or physiological effects other than a laxative action toward new users. Public water supplies with sulfate contents above this limit are commonly and constantly used without adverse effects.

SURFACTANTS

The surfactant is a synthetic organic chemical having high residual affinity at one end of its molecule and low residual affinity at the other. Its vigorous surface activity justifies not only its name, but its use as a principle ingredient in modern [illegible] the past, the principle surfactant used was alkyl benzene sulfonate (ABS); however, recently the linear alkyl benzene sulfonate (LAS) has replaced it on the market. The reason for this is that LAS is more readily degradable by biological action than is the old ABS. The 1962 United States Public Health Service Drinking Water Standards do not contain any limits for the LAS concentration; however, they do recommend a limit of 0.5 mg/l ABS inasmuch as higher concentrations may cause undesirable taste and foaming.

TOTAL RESIDUE

Total residue is a measure of the dissolved solids content in a water. Because the concentration of total dissolved solids has little physiological effect, the 1962 United States Public Health Service Drinking Water Standards have no specific requirements. It is desirable to keep the concentration of dissolved solid below 500 mg/l in municipal water supplies. However, numerous communities in the Southwest are presently using water supplies well in excess of this value, with no harmful effects.

TURBIDITY

The turbidity of water is attributable to suspended and collodial matter, the effect of which is to reduce clarity and light penetration. Turbidity is undesirable in waters used for laundry, ice-making, bottled beverages, brewing, and steam boilers. The 1962 United States Public Health Service Drinking Water Standards specify that turbidity should not exceed five units.

WATER TEMPERATURE

The temperature of surface water is variable with geographical location. Consequently, no fixed criteria are feasible. The United States Public Health Service Drinking Water Standards do not list any limits for temperature. However, any of the following conditions are considered to detract from raw water quality for public use (3):

1. Water temperature higher than 29.5°C;
2. More than 0.6°C hourly temperature variation over that caused by ambient conditions;
3. More than 2.8°C water temperature increase in excess of that caused by ambient temperature;
4. Any water temperature change which adversely affects the biota, taste, and odor, or the chemistry of the water;
5. Any water temperature variation or change which adversely affects water treatment plant operation;
6. Any water temperature change that decreases the acceptance of the water for cooling and drinking purposes.

ZINC

Zinc is an essential and beneficial element in human metabolism. Total zinc in the adult averages 2 g. Zinc deficiency in animals leads to growth retardation that is [illegible]come by adequate dietery zinc. The activity of several body enzymes is dependent on zinc (2). Excessive zinc salts act as gastrointestinal irritants and the illness is very acute but transitory. Occurring with zinc as impurities are cadmium and lead. In view of this, the 1962 United States Public Health Service Drinking Water Standards have set the concentration limit as 5.0 mg/l in order to keep the concentrations of cadmium and lead below allowable levels.

BIBLIOGRAPHY

(1) McKee and Wolf, WATER QUALITY CRITERIA, State of California, Publication No. 3-A, 1963

(2) United States Public Health Service, PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS, 1962

(3) Federal Water Pollution Control Administration, WATER QUALITY CRITERIA, 1968

(4) United States Environmental Protection Agency, MANUAL OF EVALUATING PUBLIC DRINKING WATER SUPPLIES, 1971

Table 2

Water Quality Data
(NMEIA, 1974, p. 215, 217)

	Seboyeta 1 Seboyeta Main Spring	Seboyeta 2 Auxiliary Spring Well # 2	Seboyetita (BIBO) 1 BIBO Well Well # 1	Moquino 1 Jackpile Shop Well	Moquino 2 Jackpile Well # 2
	259	259	260	256	256
Latitude	35-13-35	35-13-06	35-10-40	35-08-05	33-09-10
Longitude	107-24-00	107-23-40	107-23-41	107-19-10	107-21-65
Sodium	94.30	87.40	25.30	450.80	296.70
Potassium	1.56	1.95	7.02	2.73	1.17
Calcium	6.00	10.00	74.00	14.00	4.00
Magnesium	82.40	0.60	21.90	3.10	7.90
Iron-Total	<0.25	<0.25	0.00	<0.25	<0.25
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	2.40	3.60	7.40	27.20	18.60
Fluoride	0.49	0.50	0.33	1.55	1.50
Nitrate	<0.10	<0.10	0.08	<0.10	<0.10
Bicarbonate	255.50	223.00	341.60	404.30	384.50
Carbonate	None	None	None	None	None
Sulfate	13.40	40.50	58.30	664.00	337.90
Phosphate	-	-	0.02	-	-
Total Hardness	18.50	27.50	285.00	47.50	42.50
Alkalinity	209.40	182.80	280.00	331.40	315.20
Total Dissolved Residue	315.00	280.00	403.00	142.00	915.00
Surfactants	<0.05	<0.05	<0.05	<0.05	<0.05
pH	8.01	7.82	7.80	8.13	8.18
Odor	Negative	Negative	Normal	Negative	Negative
Color	Negative	Negative	Clear	Negative	Negative
Turbidity	0.40	0.40	0.20	0.80	0.50
Conductance Micromhos/cm 25°C	349.00	423.00	617.00	2,029.00	1,299.00
Arsenic	<0.010	<0.010	<0.010	<0.010	<0.010
Barium	Negative	Negative	Negative	Negative	Negative
Boron	Negative	Negative	Negative	0.520	0.250
Cadmium	Negative	Negative	Negative	Negative	Negative
Chromium	Negative	Negative	Negative	Negative	Negative
Copper	Negative	Negative	0.025	Negative	0.025
Cyanide	-	-	-	-	-
Lead	Negative	Negative	Negative	Negative	Negative
Mercury	-	-	-	-	-
Molybdenum	-	-	-	-	-
Nickel	Negative	Negative	Negative		Negative
Silver	Negative	Negative	Negative	Negative	Negative
Selenium	Negative	0.014	0.018	Negative	Negative
Zinc	Negative	Negative	0.070	0.060	Negative
Radium 226	-	-	-	-	-
Strontium	-	-	-	-	-
	-	-	-		

Figure 1

Ground Water Sampling Sites in the Jackpile-Paguate Area
(EPA, 1975, p.58)

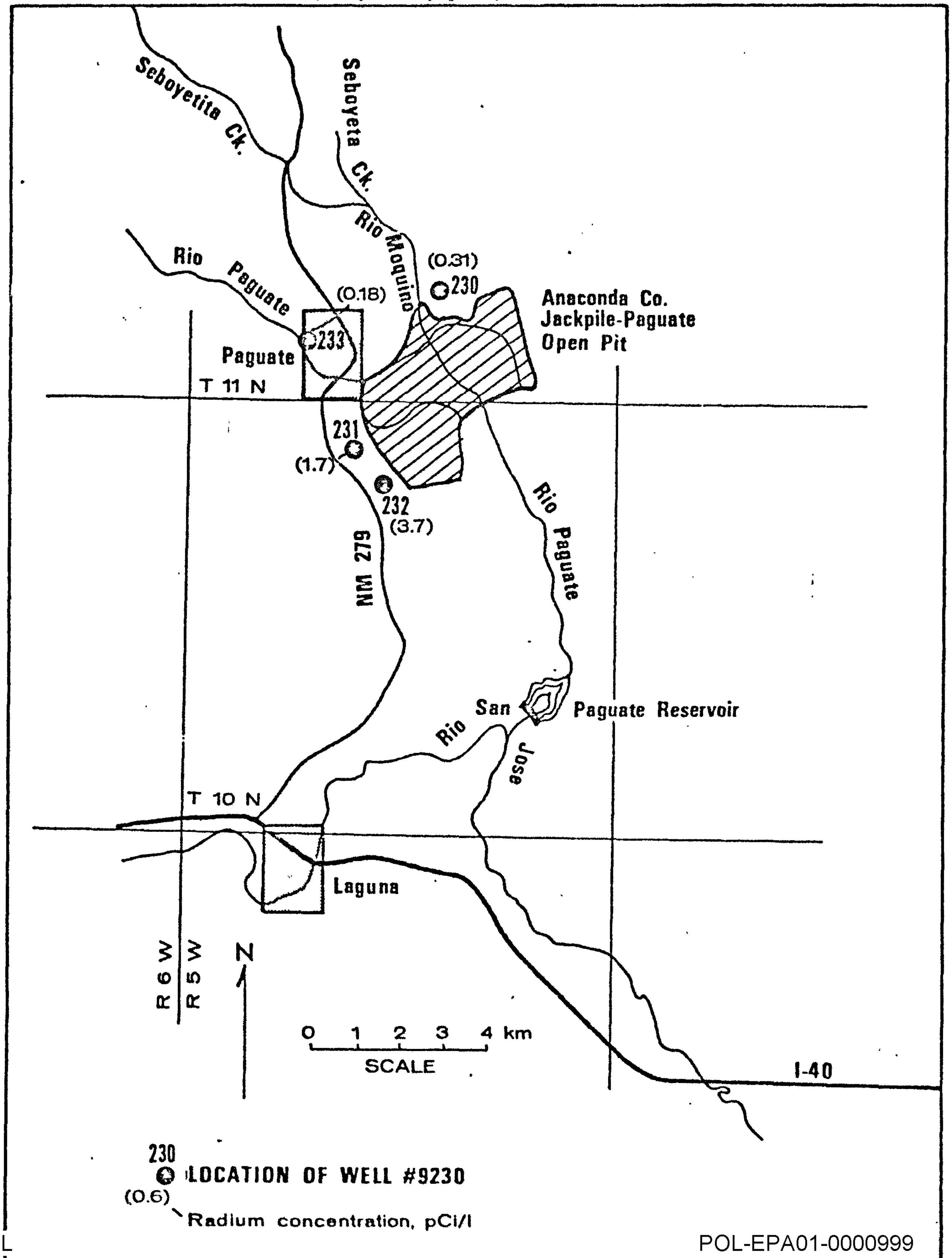


Table 3

Anaconda Water Analysis
(The Anaconda Company, 1976)

DESCRIPTION	Date	Cl ppm	SO_4 ppm	NO_3 ppm	Na ppm	Cond umhos	pH	U-Nat pCi/l	Ra-226 pCi/l	Th-230 pCi/l
Jackpile P-10 Well	2-5	24	539	2	470	1600	8.1	1.5	0.2	1.0
Jackpile New Shop Well	2-5	28	613	1	515	1500	8.1	1.4	1.0	1.5

APPENDIX IX

Archaeological Information

APPENDIX B

An Archaeological Clearance Survey

of

Eight Parcels of Land at the

Anaconda Company's Jackpile-Paguate Uranium Mine

Laguna Indian Reservation

Valencia County, New Mexico

RECEIVED

JUN 2 5 1976

U. S. Geological Survey
Carlsbad, N.M.

By

John D. Beal

School of American Research

January 6, 1976

DESCRIPTION OF SURVEY

On November 6, 7, 10, and 12, 1975, the School of American Research conducted archaeological clearance surveys of eight parcels of land at the Anaconda Company's Jackpile-Paguate Uranium Mine on the Laguna Indian Reservation, Valencia County, New Mexico. The survey was performed under Federal Antiquities Permit # 74 NM 063 and a permit from the Laguna Tribe covering only those lands within the mining lease. Dames and Moore, environmental consultants of Salt Lake City, Utah, requested that the School of American Research conduct the survey.

The areas surveyed are located within the Jackpile or Number Four Mining Leases of the Laguna Indian Reservation (T10N, R5W, Sections 1, 2, 3, 4, 5, 8, 9, 10, and 16; T11N, R5W, Sections 25, 26, 27, 33, 34, 35; and T10N, R5W, Sections 3, 4, and 5 as shown on the accompanying map). The proposed expansion of Anaconda's open pit and underground uranium mining operations will affect these areas.

Mr. William E. Gray of the Anaconda Company and Mr. John Beal of the School of American Research met at the Jackpile-Paguate Mine on November 3, 1975, for the purpose of defining the survey areas and obtaining clearance from mine personnel. Mr. Beal returned to the lease area on November 6, accompanied by Mr. Christopher Causey with whom he began an intensive survey of the designated areas. Ms. Jane Whitmore participated in the survey on November 12.

METHOD OF SURVEY

Each area was surveyed on foot in parallel linear transects with members of the survey team covering swaths of ground 50 feet in width (25 feet on either side of the line of passage). Crew members recorded signs of cultural activity, completed locational drawings of all site areas, made sketches of specific sites, and took complete sets of measurements. A small sample of ceramic materials (12 sherds) was collected at one site (A1-1). These materials, which were used in dating the site, will be returned to the Laguna Tribe. All prehistoric occupation sites were marked with yellow flagging tape, while historic occupation sites were left unmarked.

DESCRIPTION OF SURVEY AREA

The areas surveyed lie on either side of the Rio Paguate, a perennial stream joining the Rio San Jose four miles east of Laguna Pueblo. The topography of the area is "characterized by a succession of mesas and erosion valleys bounded by desert cliffs or long barren slopes: a type of landscape which results from arid climate erosion of horizontal rocks of diverse strength" (Dittert 1959; Fenneman 1931:318). The Jackpile-Paguate Mine lies eight miles due north of Laguna Pueblo where the Rio Moquino and the Arroyo Moquino merge with the Rio Paguate. These three watercourses drain a considerable portion of the Mount Taylor watershed which lies to the north and west. The Arroyo Moquino serves to drain the west side of Gavilan Mesa, the most prominent landmark in the immediate area.

The majority of the areas surveyed is marked by gently sloping, treeless, alluvial valleys which are cut by deeply entrenched arroyos and bordered by outcrops of caprock, components of the Mesaverde Formation. Only the westernmost parcel (#7) differed from this norm; there the foothills of Mount Taylor rise to a considerable height (7,400 feet) and concentrated growths of piñon and juniper provide cover over the exceedingly rocky soil.

Valley bottoms below the mesas are populated by various grasses and low shrubs. Isolated small junipers occur where the caprock ends or where micro-environmental conditions permit. Cacti and members of the yucca family are not abundant. In comparison, the steep hillsides and mesa tops are typified by growths of piñon-juniper, various grasses, fourwing saltbush, prickly pear, and mamilaria cactus.

Mining operations in the vicinity have caused considerable impact on the original topography. Open pit mining operations, ancillary roads, backfill dumps, and drill holes are by far the most dominant features in all areas.

ARCHAEOLOGICAL BACKGROUND

Neither the Laguna Indian Reservation nor the general Paguate area has ever been the subject of detailed-archaeological investigation. While considerable work has been done to the south and west of the Laguna Reservation by A. E. Dittert (1949 and 1959), R. J. Ruppe (1953), and R. Wiseman (1974), their investigations deal with the Laguna area in a peripheral way. Some work has been done in the Paguate area, notably by Eastern New Mexico University under the directio

Irwin-Williams, and in the form of survey activities by Gerald Dawson; however, the results of their work have not been published. Despite the lack of data available, a brief profile of the area's prehistory can be made by synthesizing Dittert's, Ruppe's and Wiseman's observations together with the information gained from M. A. Beach in a personal communication. (Mr. Beach, who is presently at Grossmont College, El Cajon, California, participated in the activities of Eastern New Mexico University in the survey area.)

The earliest probable occupation in the area dates to the Cody Phase of the Paleoindian period. W. James Judge (1973) has documented a site of this horizon not more than 10 miles east of the Paguate area and north of the Rio San Jose. There is some evidence that materials of the Cochise culture have also been observed in the area (Beach pers. com.). In any event, it is probable that the area to the south and east of Paguate was the province of Paleoindian hunters and that increments of this population did enter and exploit the eastern foothills of Mount Taylor. The dates of these incursions may have ranged from 10,000 B.C. to 500 B.C. and to perhaps later. During the period 2500 B.C. to approximately 1 A.D., Archaic period hunters used the area. Their camps occurred on the benches and outcrops of the Mesaverde Formation below the high mesas (Beach pers. com.; Dittert 1959). Both the Paleoindian and Archaic occupations in the area are similar in their utilization of lithic tools and the location of their habitations above the valley floor. The high mesas were occupied by Basketmaker peoples, and documentation for White

Mound Phase Basketmaker III sites is well established by both Dittert and Ruppe in the district south of Laguna along ~~the Malpais~~ (Cebolleta Mesa ~~Region~~).

Early pueblo settlements are documented (Dittert 1949, 1959; Ruppe 1953; Wiseman 1974) in the Cebolleta Mesa area south of Paguate as well as in the surrounding area. The occupational sequence for the Laguna area can be considered similar to that established by Dittert for the Cebolleta Mesa region as a whole (see Table 1).

Late Pueblo III settlement in the area was confirmed during the survey by the presence of black on white wares and White Mountain red wares (including Houck--an early polychrome) at a small site. Cubero Phase sites have been noted to the south of the survey area (Dittert 1959), and there is little doubt that similar sites exist in the more immediate vicinity. That the region was dominated both physically and economically by Acoma Pueblo was well documented by Coronado at the time of his entrance into New Mexico (Boulton 1971; Hammond and Rey 1940). In 1697/98, increments of population from the Rio Grande pueblos were resettled along the Rio San Jose east of its confluence with Acoma Creek where a small Acoman population was already living. In 1699, Governor Cubero visited the new settlement and named it San Jose de la Laguna. This was later shortened to Laguna or Laguna Pueblo in historic times.

Farming has figured prominently in Laguna's economic picture, and several small farming communities were established in favorable locations along the Rio San Jose and its tributaries. Paguate was one of these villages and is first documented as

Table 1

Prehistoric Occupation in the Cebolleta Mesa Region

Cultural Periods	Dates	Pecos Classification
Acoma Phase	1600-Present	Pueblo V
Cubero Phase	1400-1600	Pueblo IV (Late)
Kowina Phase	1200-1400	Pueblo III-Pueblo IV
Pilares Phase	1100-1200	Pueblo III
Cebolleta Phase	950-1100	Pueblo II
Red Mesa Phase	870-950	Early Pueblo II
Kiatuthlanna Phase	800-870	Pueblo I
White Mound Phase	700-800	Basketmaker III
Lobo Period San Jose Period	2500 B.C.-A.D. 700	Archaic
Cody Phase Cochise Phase	10,000 B.C.-2500 B.C.	Paleoindian

existent prior to 1849. The inhabitants of Laguna proved more receptive to animal husbandry, primarily sheep herding, than most pueblos of the day and, by 1754, were noted for their large herds. Herding continues to be the primary activity requiring land today although cattle have generally replaced sheep within the last 50 years.

ARCHAEOLOGICAL EVALUATION OF SURVEYED AREAS

The entire survey project was conducted with respect to eight specific survey areas, each of which will be dealt with individually in the following discussion.

Survey Area A1

An intensive survey of area A1 resulted in the delineation of 5 occupation sites, 4 of which are historic, apparently related to the husbandry of sheep, and one of which is a prehistoric pueblo site. An inspection of the sandstone bench above the pueblo site resulted in the discovery of an archaic lithic scatter. This site lies out of the survey area, but its presence does substantiate the geographic stratification of sites mentioned previously.

Site A1-1

This site occupies a low hummock of alluvial soil between the two arms of Gavilan Mesa which open to the northwest and the Arroyo Moquino. Several small junipers populate this rise and constitute the only trees in the area. Evidence of occupation extends for a distance of 100 meters along the crest of the hummock and consists of ceramic materials. Architectural indications of occupation (as shown on Site Plan 1) are: a single rectangular rubble mound of masonry debris less than 3 meters square, a circular rubble mound 2 meters in diameter, 2 isolated fire hearths, and a possible pit structure.

The fact that the isolated hearths and possible pit structure are somewhat removed from the other site remains may indicate that the manifestation is multi-component in nature; i.e., pueblo and basketmaker. There were, however, no diagnostic basketmaker materials evident on the surface. The presence of Santa Fe, Socorro, and Esquevada painted wares in addition to Houck Polychrome tends to indicate occupational dates from 1250 to 1350 A.D.

Site Al-2

This site is located approximately 65 meters north northeast of site Al-1 abutting the first bench of caprock above the valley floor. A small alcove or rincon is located directly to the east of the feature and is supposedly the result of entrenchment of a small drainage in this area. The manifestation consists of a rounded "L" shaped wall (semi-circular) of unaltered, simple sandstone masonry. This wall, in conjunction with the caprock forms an enclosure roughly 3 X 4 meters square; the wall ranges from .30 to .75 meters in height.

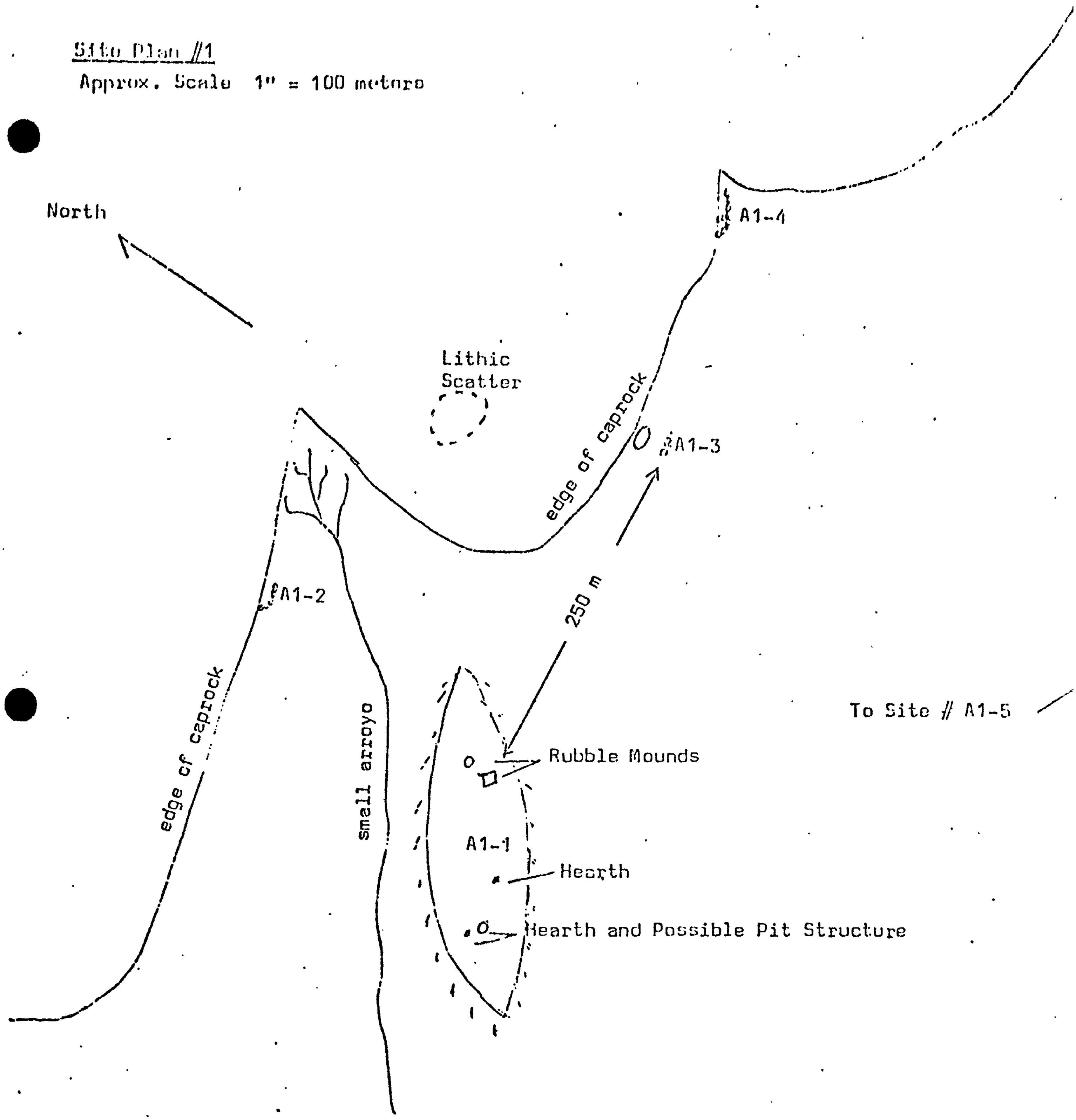
There is no indication that this feature is of prehistoric origin. Sheep dung and metallic trash around the site indicate that it is of historic manufacture and probably related to sheep herding activities in the area. Such a structure may well have served as a lambing pen or temporary herding shelter.

Site Al-3

Site Al-3 consists of a simple rock mound associated with

Site Plan #1

Approx. Scale 1" = 100 meters



isolated sandstone pillar along the rim of caprock 250 meters east of site Al-1. Unshaped sandstone slabs have been stacked in a single pile measuring roughly 2 meters in length, .75 meters in width and .60 meters in height. Although cultural material in the immediate area was nonexistent, the feature is believed to be of historic origin. The spatial relationship between the rock pile and the natural pillar may indicate that the rock pile is a marker of some type. Site Al-4 is located a short distance to the east in a small alcove, and some connection between the two is possible.

Site Al-4

A small alcove 50 meters to the east of Site Al-3 is the location of two concentric stone walls which are probably the remains of an historic shelter and a sheep pen. Both of these structures abut the first bench of caprock. The westernmost and smallest structure is composed of dry-laid coarse masonry which extends in an arc from northwest to southeast. At the northwestern extremity the stone wall abuts the cliff face and at the southeast end, abuts the west wall of a larger sheep pen. The smaller structure encompasses roughly 4 square meters of surface area, and the walls maintain a height of more than .50 meters. The larger structure (sheep pen) is constructed in similar fashion and of similar materials; however, it evidences signs of an entrance to the south (a breach in the wall) and encompasses 5 times as much surface area. The presence of sheep dung in the larger enclosure indicates that the features were used by shepherds running stock along the

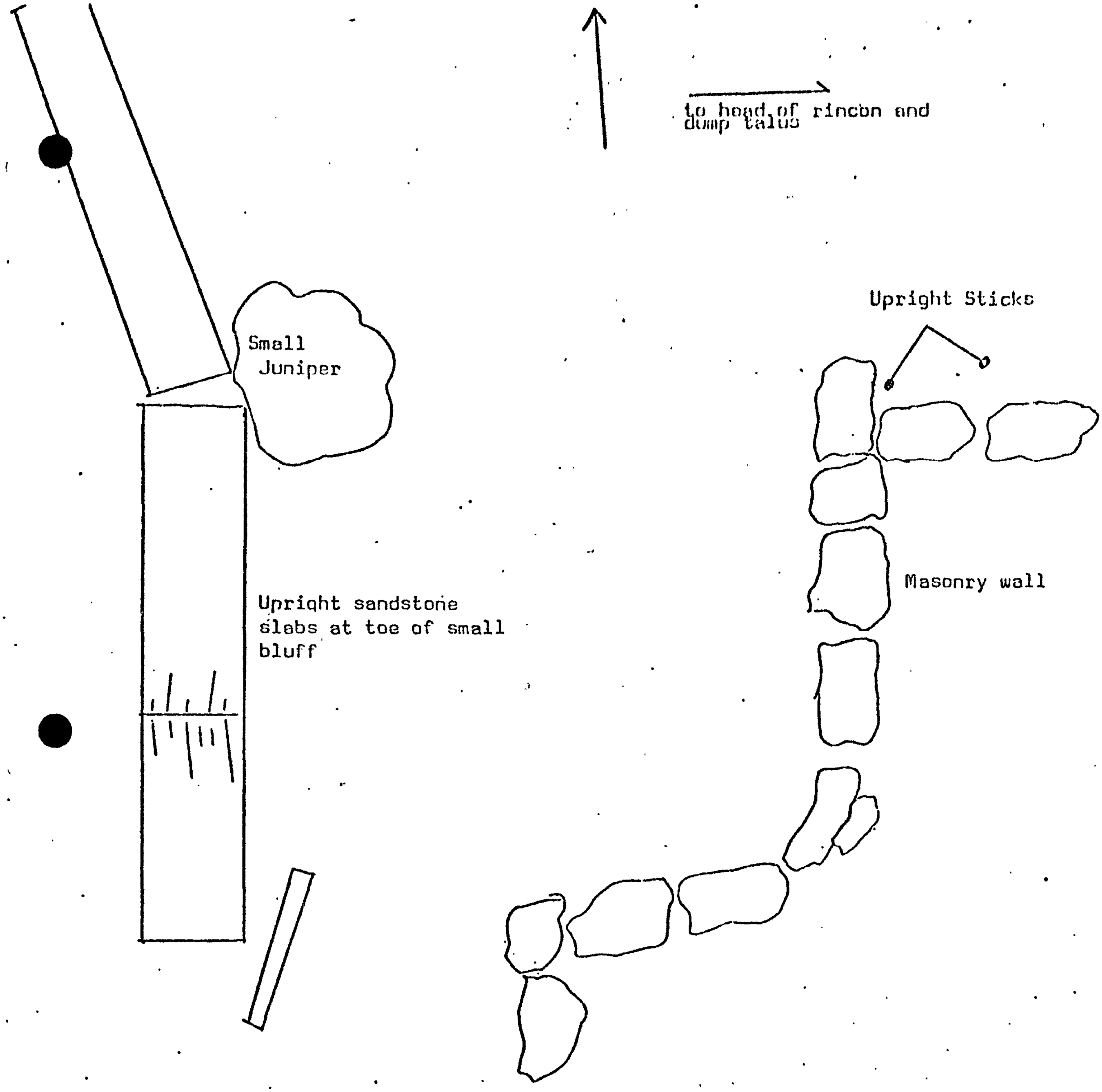
Arroyo Moquino. No metallic or glass materials were associated with the site.

Site A1-5

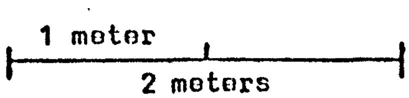
Site A1-5 is located 340 meters southeast of site A1-1 toward the head of the rincon and on the opposite side of the drainage. The site occurs at the toe of a small ridge which extends into the bottomlands. The site is bordered on the west by two large segments of sandstone slab marking the toe of the ridge and lodged in an upright or vertical position. Two meters to the east of these naturally erected stones is a rough "L" shaped wall of crude masonry without mortar. The alignment turns several 90 degree angles and is marked by two upright sticks embedded in the ground at the crux of the angles formed at its northern extremity. These sticks are of naturally peeled and weathered piñon pine, .03 meters in diameter and .35 meters in height above the ground. The wall itself ranges from .10 to .75 meters in height. The absence of any cultural material related to the site precludes any definitive assignment of cultural period; however, the similarity of construction to herding shelters and stock pens in the same area indicates historic origin. The structures' exact function and the significance of the two upright sticks at the north end of the structure are problematical.

Survey Area A2

The survey of area A2 resulted in the documentation of two sites, both of which appear to belong to the historic period of occupation. The first is a series of six masonry alignments forming walls and partial enclosures, which may be the remains of an abandoned sheep camp. The second consists of the remains



Site #A1-5
Historic Herding Shelter or Wind Break



of a possible circular shrine or marker, evidently abandoned.

Site A2-1

Site A2-1 lies at the base of the first bench of caprock and consists of one "L" shaped windbreak or shelter on the south side of a small tributary drainage of the Arroyo Moquino, and three sections of masonry wall, a probable storage structure and a cairn on the north (as shown on site plan 2). Pertinent information for each of these structures is as follows:

Structure #1 Windbreak (temporary domicile?)

length of N-S wall	1.64 meters
length of E-W wall	1.74 meters
minimum wall height	.28 meters
maximum wall height	.85 meters
wall width	.35 meters
Construction:	Crude, coursed, simple masonry without mortar; vertical slabs at both ends of wall and at 90 degree juncture.

Structure #2 Sheep Pen

length of N-S wall	2.50 meters
length of E-W wall	9.0 meters
distance from edge of arroyo	1.50 meters
wall height	.10-.85 meters
Construction:	Crude, coursed, simple masonry without mortar; 90 degree abuttment near arroyo is indistinct (washed out).

Structure #3 Storage Bin

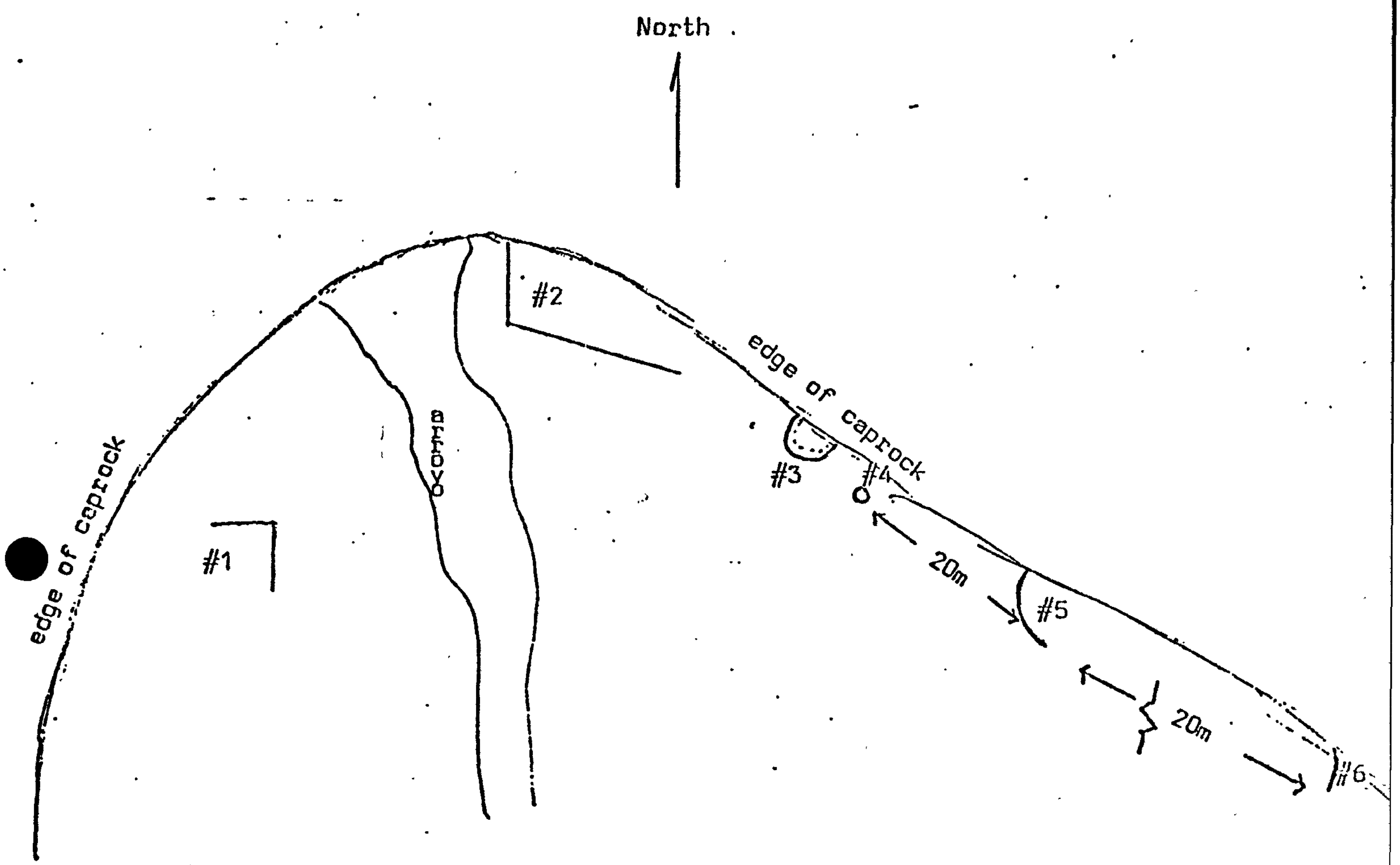
diameter N-W	1.70 meters
diameter E-W	1.05 meters
wall height	.25-.85 meters
Construction:	Located under a small overhang of caprock; crude, coursed, simple masonry without mortar; circular.

Structure #4 Cairn

height	.55 meters
width	.35 meters
Construction:	6 rocks piled on top of each other, general decrease in size.

Sito Plnn # 2

Sito # A2-1
Approx. Scalo: 1" = 5 metors



Structure #5 Windbreak or Lambing Pen

length of wall	2.25 meters
width of wall	.40 meters
height of wall	.48-.70 meters
Construction:	Crude, coursed, simple masonry without mortar; abuts the caprock and is open to the southeast.

Structure #6 Storage (destroyed?)

length of wall	1.60 meters
height of wall	1.05 meters
Construction:	Located in a small cleft in caprock; large stones laid in crude courses without mortar; 8 large rocks used in wall segment.

It is generally apparent that these structures form a single site by virtue of their similarities of construction and proximity. A conversation with Mr. E. P. Scarracino of Paguate revealed that this general area was the scene of considerable herding in the 1920's and that some rather similar structures in the area were constructed then. It is probable that these structures relate to this period or before.

Site A2-2

This manifestation is located at the top of the caprock and 12 meters from its edge. It is also a short distance (40 meters) south of the Laguna Indian Reservation boundary. It consists of a semicircle of simple stone masonry 1.25 meters in length and from .12 to .48 meters in height. The feature is situated in such a way that the masonry wall functions as an extension of a circular depression in the surface of the caprock. When the depression and masonry wall are considered parts of the same entity, a circular area 1.80 meters in diameter is formed. No materials of cultural significance were observed in conjunction with the feature; however, no attempt to disturb the soil inside the feature was made. Judging from the location of the feature and its form, it is probable that it served as either a shrine or marker.

Survey Area A3

No materials of archaeological or historical significance were documented for this area.

Survey Area A4

No materials of archaeological or historical significance were documented for this area.

Survey Area A5

No materials of archaeological or historical significance were documented for this area.

Survey Area A6

No materials of archaeological or historical significance were documented for this area.

Survey Area A7

No materials of archaeological or historical significance were documented for this area.

Survey Area A8

Three sites were located in this area, all of which were historic. The first (A8-1) appears to be a shrine area, while the second (A8-2) is an abandoned domicile. The third (A8-3) is a stock (goat) pen.

Site A8-1

This site is located on the east side of a small arroyo draining into Oak Canyon from the north and occupying a position in the center of the South Dump expansion. The site lies 20 meters southwest of the toe of the South Dump. A series of three stone cairns marks a pocket of deflation. Two additional stone cairns are located to the north between the deflated area and the South Dump, and a single isolated cairn is located 25 meters to the southeast. The survey party was informed of the presence of a shrine in this general area, and it is assumed that this series of six cairns and the pocket of deflation is the one referred to. No cultural materials were associated with the immediate area of the cairns.

Site A8-2

Four hundred meters east of site A8-1 lies site A8-2 which consists of two mounds of masonry room rubble, a horno, a pile of wood chips, a small pocket of trash including chipped stone, glass and bottle caps and an iron stove. The presence of glass and metal tend to establish a recent date of occupation. The fact that no enclosures for stock are evident close to these ruins would tend to indicate that the features served primary domiciliary functions and were probably not related to temporary herding in the area; however, it is possible that site A8-3 is related to this site.

Site A8-3

Three hundred meters south of the east edge of the South Dump, along the edge of the caprock lies a single juniper branch and brush corral with metal watering trough. The corral is semicircular and situated to take advantage of the cliff face formed by the caprock. Dimensions are 15 X 8 meters, the back wall being formed by the cliff face. An entrance is located at the front of the corral (south southwest) and is 1.50 meters in width. The watering trough is located outside the enclosure and to the right of the entrance. Judging from the dung evident, it is probable that the last occupants were goats.

RECOMMENDATIONS FOR CLEARANCE

The discovery of one prehistoric occupation site in the areas surveyed necessitates some action. The site has been directly impacted by the drilling of test holes in the vicinity and if further development of the area will result in additional surface alterations, mitigative steps will be necessary. Because this particular aréa is slated for underground mining, it is possible that further damage can be avoided if all surface alterations are restricted. It is suggested that this alternative be considered. The immediate area now receives little traffic, and it is probable that if this trend can be continued, there will be little or no impact on the site.

The numerous historic sites in areas A-1, 2, and 8 are of no apparent archaeological significance; however, clearance from tribal officials should be gained before any are altered. This applies especially to those sites which may be shrined (sites A2-2 and A8-1), as they may have and continue to have considerable significance to the area's inhabitants. The following is a complete list of recommendations for clearance:

Area	Recommendation
A1	It is recommended that archaeological clearance be granted provided all land altering activities near site A1-1 are avoided. Further, clearance from tribal officials should be gained before any of the historic sites documented are destroyed or altered.
A2	It is recommended that archaeological clearance be granted in area A2 provided tribal officials are contacted with respect to sites A2-1 and A2-2.

Area	Recommendation
A3	It is recommended that archaeological clearance be granted for all of area A3.
A4	It is recommended that archaeological clearance be granted for all of area A4.
A5	It is recommended that archaeological clearance be granted for all of area A5.
A6	It is recommended that archaeological clearance be granted for all of area A6.
A7	It is recommended that archaeological clearance be granted for all of area A7.
A8	It is recommended that archaeological clearance be granted provided tribal officials are contacted with respect to sites A8-1, 2, and 3.

An Additional Note on Historic Sites

There may be some question as to whether some of the historic sites documented in the survey are of Navajo or Pueblo origin. No truly diagnostic materials were encountered which shed light on this point. Admittedly the masonry style of these structures is not even remotely similar to that observable in the town of Paguate or even in some of the outlying buildings. However, all corrals in the region appear to have been constructed in the same way (crude, simple, coursed masonry without mortar) no matter what their associations were with pueblo towns or other structures. While it is generally conceded that both Navajos and Pueblos utilized the area, there is considerable confusion as to who did what, where, and to whom such structures may be attributed (Littel and Graham).

Bibliography

Bolton, Herbert E.
1949 Coronado, Knight of Pueblos and Plains. University of New Mexico Press, Albuquerque, New Mexico.

Dittert, A. E.
1959 Culture Change in the Cebolleta Mesa Region, Central Western New Mexico. Unpublished Ph.D. Dissertation, University of Arizona.

Eggan, F.
1950 Social Organization of the Western Pueblos. University of Chicago Press, Chicago, Illinois.

Ellis, F. H.
1959 Southwestern Journal of Anthropology. Vol. 15, No. 4, Winter.

Fenneman, N. M.
1931 Physiography of the Western States. McGraw-Hill, New York.

Hammond, G. P. and Rey, A.
1940 Narratives of the Coronado Expedition, 1540-1542. Coronado Cuarto Centenial Publications, 1540-1940, Vol. 2, Albuquerque.

Judge, W. J.
1973 PaleoIndian Occupation of the Central Rio Grande Valley in New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

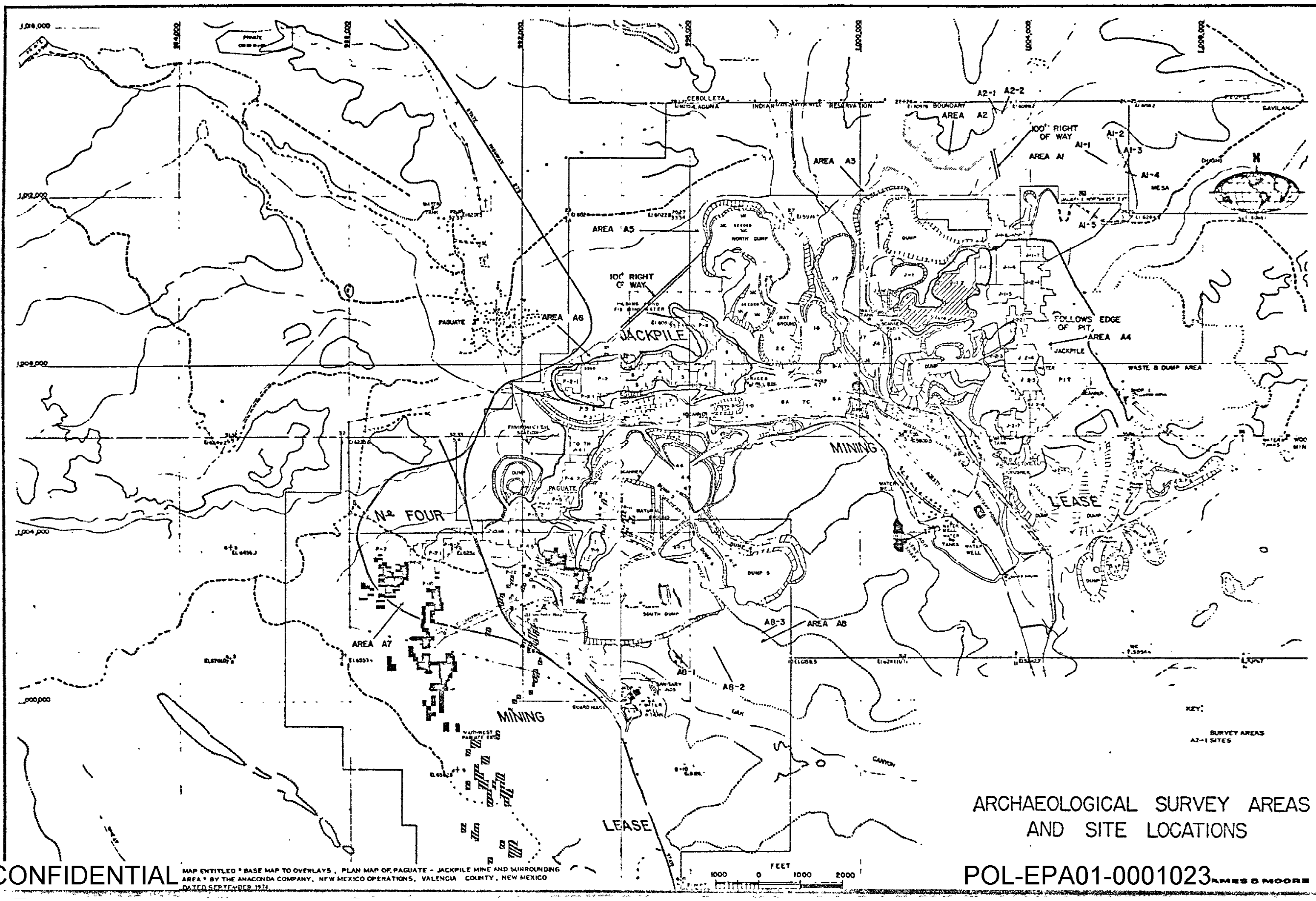
Littel & Graham
Records of Proposed Findings of Fact in Behalf of the Navajo Tribe of Indians in the Laguna-Acoma Overlap. Indian Claims Commission.

Northrop, S. A.
1942 Minerals of New Mexico. University of New Mexico Bulletin, Geological Series, Vol. 6, No. 1. Albuquerque, New Mexico

Ruppe, R. J. Jr.
1953 The Acoma Culture Province, An Archaeological Concept. Unpublished PH.D. Dissertation, Harvard University.

Wiseman, R.
1974 The Malpais Reconnaissance, An Archaeological Inventory and Evaluation of some Prehistoric Occupation sites in the El Malpais Planning Unit, Socorro District, Bureau of Land Management.

Wormington, H. M.
1959 Prehistoric Indians of the Southwest. The Denver Museum of Natural History, Denver, Colorado.


ARCHAEOLOGICAL SURVEY AREAS
AND SITE LOCATIONS
AREA A1
AREA A2
AREA A3
AREA A4
AREA A5
AREA A6
AREA A7
AREA A8
A2-1
A2-2
A1-1
A1-2
A1-3
A1-4
A1-5
A8-1
A8-2
A8-3
100' RIGHT OF WAY
FOLLOWS EDGE OF PIT
JACKPILE
MINING
LEASE
Nº FOUR
PAGUATE
CEBOLLETA
INDIAN
RESERVATION
MESA
GAVILAN
NORTH DUMP
SOUTH DUMP
WASTE & DUMP AREA
PIT
WATER WELL
CANYON
KEY:
SURVEY AREAS
A2-1 SITES
FEET
1000 0 1000 2000
MAP ENTITLED "BASE MAP TO OVERLAYS, PLAN MAP OF PAGUATE - JACKPILE MINE AND SURROUNDING AREA" BY THE ANACONDA COMPANY, NEW MEXICO OPERATIONS, VALENCIA COUNTY, NEW MEXICO
DATED SEPTEMBER 1974

APPENDIX X

Bureau of Indian Affairs Comments

United States Department of the Interior
GEOLOGICAL SURVEY
P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

March 19, 1976

Memorandum

To: Superintendent, Southern Pueblos Agency, BIA, Albuquerque, New Mexico

From: Area Mining Supervisor, SRMA, USGS, Carlsbad, New Mexico

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Mines on Laguna Tribal Lease No. 4

Enclosed are two copies of the plan (two volumes with map pocket) for your review. Please give us your recommendations, consistent with the requirements of the lease terms, for the protection of nonmineral resources and for the reclamation of the land surface affected by the plan.

Dale C. Jones
Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:nb

Enclosure:

United States Department of the Interior
GEOLOGICAL SURVEY
P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY REFER TO.

March 29, 1976

Memorandum

To: Superintendent, Southern Pueblos Agency, BIA, Albuquerque, New Mexico

From: Area Mining Supervisor, SRMA, USGS, Carlsbad, New Mexico

Subject: Addendum to The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Mines on Laguna Tribal Lease No. 4

Enclosed are two copies of the above addendum which are to be included with the plans submitted to your office with our memorandum of March 19, 1976. Any future addendums will be submitted to your office upon receipt.

Dale C. Jones
Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:cj

Enclosures

United States Department of the Interior
GEOLOGICAL SURVEY
P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

May 21, 1976

Memorandum

To: Superintendent, Southern Pueblos Agency, BIA, Albuquerque, New Mexico

From: Area Mining Supervisor, SRMA, USGS, Carlsbad, New Mexico

Subject: The Anaconda Company's Proposed Mining and Reclamation Plan for the P-15 and P-17 Uranium Mines on Laguna Tribal Lease No. 4

Enclosed are two copies of the company's addendums to the subject plan which was submitted in duplicate to your office with our memorandum of March 19, 1976. These addendums should be included as parts of the plans.

Dale C. Jones
Dale C. Jones
Mining Engineer
for Area Mining Supervisor

DCJ:cj

Enclosures

APPENDIX XI

Miscellaneous Information

United States Department of the Interior
GEOLOGICAL SURVEY
P.O. BOX 1716
CARLSBAD, NEW MEXICO 88220

IN REPLY
REFER TO:

March 19, 1976

COUNTY CLERK

Mrs. Pat I. Heth

Valencia County Court House

Las Lunas, New Mexico 87031

Dear Mrs. Heth:

Enclosed is a public notice listing this week's new mining plans and/or significant revisions to previous mining plans. We suggest these notices be posted in some prominent place for public viewing and that local news media be advised of their availability in your office.

Sincerely yours,

Dale C. Jones
Dale C. Jones
Mining Engineer
for R. S. Fulton
Area Mining Supervisor

NEW MEXICO PLANS OR MAJOR MODIFICATIONS OF EXISTING PLANS
SUBMITTED FOR APPROVAL

Release Date March 19, 1976

Date	Lessee or Operator	Lease Number	Location	County	State
3/18/76	The Anaconda Company	Laguna Tribal Uranium Lease No. 4	T10N, R5W, NMPM Sec. 3, S½S½NW¼, SW¼ Sec. 4, S½S½N½, S½ Sec. 5, SE¼NW¼, Lots 1 & 2, S½NE¼, E½SW¼, SE¼ Sec. 8, NE¼NW¼, N½N½SE¼NW¼, NE¼, NE¼SE¼, E½W½SE¼SE¼, E½SE¼SE¼ Sec. 9, All Sec. 10, NW¼, N½SW¼, N½S½SW¼ Sec. 16, N½	Valencia,	New Mexico

A copy of the plan may be reviewed at the office location given below. Pertinent comments are solicited from anyone affected by this proposal. Such comments should be filed within 30 days from the date of this release. Response t ıly filed will be considered in the preparation of the environmental analysis. Responses should be addressed to the mining supervisor at the following address:

Area Mining Supervisor
Conservation Division
U. S. Geological Survey
Federal Building
114 South Halagueno
P. O. Box 1716
Carlsbad, New Mexico 88220

LEWIS L. ORIARD, INC.

GEOTECHNICAL CONSULTING

3502 SAGAMORE DRIVE
HUNTINGTON BEACH, CALIFORNIA 92649

(714) 846-1515
or (714) 835-6886

REPORT OF INVESTIGATIONS

SEISMIC EFFECTS OF BLASTING OPERATIONS
OF
ANACONDA MINERALS COMPANY
ON
THE VILLAGE OF PAGUATE, NEW MEXICO

Prepared for

Anaconda Minerals Company
Grants, New Mexico

August 12, 1982

SEISMIC EFFECTS OF BLASTING OPERATIONS OF ANACONDA MINERALS COMPANY ON THE VILLAGE OF PAGUATE, NEW MEXICO.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

In accord with the request of Anaconda Minerals, I have directed my attention to the question of blasting effects on the homes in Paguate, west and northwest of the past mining operations at the Jackpile, North Paguate and South Paguate mining areas.

I have discussed the past drilling and blasting practices at this site with Mr. Erwin Green of Anaconda, and have reviewed some of the company's records and files to acquaint myself with the operations. In addition, I have studied reports and data prepared by Mr. Philip Berger who was retained by Anaconda to monitor ground vibrations generated by the blasting operations.

In order to become familiar with the various repairs, remodeling and maintenance work done in Paguate by Anaconda over the years, I have met with Mr. Basil Ward and have spent some time with him in touring Paguate, at which time I observed the type of work his crews performed and the types of home construction to be found there.

I have also met with Mr. Fred Mirabal of Anaconda, have inspected the exterior of his home in San Rafael, and have viewed the general conditions of the buildings in San Rafael, an area far removed from any of the blasting activities.

In addition, I have driven through other villages and occupied areas in the region, and have studied files showing pre-blast inspections made of other, similar residences in New Mexico, as well as viewing miscellaneous commercial buildings in Albuquerque.

I have also studied the earthquake history of the region and have reviewed a summary of weather data.

The following is a brief summary of my observations and conclusions:

PRINCIPAL OBSERVATIONS

1. In Paguate, I did not find a correlation between building cracks and vibration intensity. I observed fewer cracks in the area near the blasting, and more cracks as I moved farther away from the blasting areas. Of course, this is the reverse of what one would expect to find if the blasting were to have caused the building cracks.

2. The cracks I observed in the buildings in Paguate are of the same type and character as those I observed in similar buildings in other areas where no blasting has taken place, such as in nearby villages, other occupied areas in the region, other areas around the United States, and in many foreign countries.

3. The conditions I observed were typical cases of damage and deterioration caused by static (non-vibratory) forces, such as shrinkage, expansion, settlement, temperature and humidity effects, water damage, age, and similar forces. Although I did not inspect every building in Paguate, and saw only the exteriors, I did not see any evidence of vibration damage. Rather a contrary correlation was shown, as stated in paragraph 1. Each type example I saw in Paguate can be found many times over in nearby areas where no blasting has taken place. These conditions are commonplace, not only in this area, but in most areas.

4. Many buildings in Paguate were given a pre-blast inspection, including photographic coverage, in 1961. The photographs serve to document the same conditions that can be seen today after the blasting operations have been closed down.

5. A portable seismograph was used to record the ground vibrations in and near Paguate for about 1400 to 1500 blasts during Anaconda's operations. None of the recorded vibrations was of sufficient intensity to cause structural damage to buildings.

PRINCIPAL CONCLUSIONS

Comparing the vibration data with what I observed of the homes in Paguate and with what information was given to me concerning these homes, my principal conclusions concerning blasting effects are these:

1. The blasting operations did not cause any structural damage to the homes in Paguate.

2. Over-all, the general condition of the village is better than it was before the mining operations began.

3. Anaconda has expended some 1 to 1¼ million dollars or more on the homes in Paguate. An inspection of Anaconda's records shows that a portion of these expenditures are identified as structural repair or repair of blast damage. However, a review of the type of work done and an inspection of the village show that this was merely a convenient way of categorizing alleged damage. The funds were spent largely on various

alterations, remodelings and improvements of a structural nature which are completely unrelated to the levels of vibration that were generated by the blasting operations. Further, the work done on these homes substantially increased the intrinsic values of the properties.

We can safely presume that something well in excess of $1 million has been spent to maintain good will and good public relations with the neighboring residents of Paguate, and not to repair blast damage.

4. On the other hand, the reactions of nearby residents has been perfectly normal and predictable. It would have been an extremely rare case if extensive damage claims had not been made, despite the lack of actual damage. The levels of vibration were well above those that are easily perceived by people, and it is a perfectly normal response for the average person to believe that motions which are so easily felt must cause damage. This sensitivity of people is the reason that pre-blast inspections are made and the reason that seismographs are used so extensively. If people were not more sensitive than the houses they occupy, there would be no need for these efforts because vibration specialists can provide safe guidelines without the inspections and without the seismographs.

BLASTING VIBRATIONS TRANSMITTED TO PAGUATE

During the life of the open-pit mining operations conducted by Anaconda, blasting took place at various locations within the three open-pit areas east-southeast of Paguate. The vibrations transmitted to Paguate during these operations were quite variable because of the variations in distance and in the blasting patterns. The minimum distance was approximately 1000 ft. to the nearest home and about 5000 ft. to the far side of the village. The more distant blasting took place at distances of the order of several miles.

One of the more important factors about ground vibrations generated by blasting operations is the manner in which these vibrations die out with distance. This diminishing of intensity is known as attenuation. The vibrations die out or attenuate in a regular manner which is easily calculated. Each time the distance from the blasting is doubled, the vibration is reduced to being about 1/3 as much as before. For example, at 2000 ft., the vibration is about 1/3 that which is found at 1000 ft. At 4000 ft., the vibration is about 1/9 that which is found at 1000 ft. At 8000 ft., the vibration is about 1/27 that which is found at 1000 ft.

This relationship between distance and vibration intensity is very important in analyzing the potential for damage, or in determining whether the observed building conditions could be related to blasting. There must be some reasonable relationship between the amount of damage that occurred and the amount of vibration that occurred. One very striking characteristic of blast damage is that it becomes dramatically more intense as we approach the blast area. Of course, that would have to be true because of the very great increase in the intensity of the vibration at the closer distance. A person who is familiar with the subject would know that if the vibration is sufficiently intense to cause damage at a distance of 1 mile, it would cause great destruction to similar buildings at a distance of only 1000 ft.

Vibration intensity for blasting is usually expressed in terms of "particle velocity", that is the velocity of a particle on the ground surface as the vibration wave passes. During blasting operations such as those conducted in this case, the ground surface undergoes a small movement up and down, back and forth, and comes to rest exactly where it started. How fast this movement takes place is a measure of the vibration intensity and helps us determine whether or not the vibration is capable of causing damage to buildings. In the United States, it is customary to measure particle velocity in inches per second, and I will use those units in discussing the vibrations in this case. In other countries, it is more common to use metric units rather than English units. Today, most of the regulations, codes, laws and project specifications which govern blasting vibrations do so by limiting them in terms of particle velocity, though some include references to other characteristics of vibration.

Instruments can be designed to measure either the displacement, velocity or acceleration developed by a vibration. On this project, the portable seismograph that was used to record the vibrations did so by producing a permanent photographic recording of the displacement and the frequency of the vibration. From this, the particle velocity was calculated directly.

For those who may have heard some reference to the velocity of seismic waves, it is important to understand that particle velocity is a different item than the transmission velocity of a wave passing through the area. The wave will have the same transmission velocity whether of high or low intensity. The transmission velocity is not changed by the intensity of the wave, but is determined by the nature of the material through which the wave passes. It is different for air, water and rock, for example. On the other hand, the particle velocity is determined by the intensity of the wave. For example, a loud sound and a very quiet sound have the same transmission velocity, but a loud sound has a higher particle velocity.

The particle velocity of a ground vibration is a combination of how far the ground moves (its displacement) and the frequency of the motion (how many times it moves through a cycle in one second of time). A typical vibration for the case we are discussing here had a displacement in the range of several thousandths of an inch (about the thickness of a sheet of typing paper) and a frequency of several cycles per second.

A Sprengnether portable seismograph was used to monitor the blasting operations. At various times, the seismograph was placed at any one of about a dozen monitoring locations in the village, or southeast of the village closer to the mining operations. The seismograph was set out for 1400 to 1500 blasts. It was sometimes difficult for the seismograph operator to know precisely when a blast would detonate, and a few of these blasts were missed. About 1400 recordings were obtained. From a review of the data, a selection was made of the fourteen strongest vibration events recorded during the mining operations. Ten of the fourteen strongest vibrations were recorded on the old road near the mine. This road was later removed by the advancing mining operations. When these ten recordings are adjusted for the additional distance to the village, it is noted that the vibrations actually transmitted to the village by these ten blasts were not of any significance, ranging from only about 0.3 to 0.5 in./sec. at the closest house to about 0.07 to 0.08 in./sec. on the far side of the village.

The remaining four strongest vibrations were noted as follows:

Shot No. 75	11/3/67	0.65 in./sec. at Hershey's (1600 ft.)
Shot No. 143	6/11/68	1.36 in./sec. at Hershey's (1674 ft.)
Shot No. 217	10/24/68	0.56 in./sec. at Hershey's (2198 ft.)
Shot No. 429	9/13/69	0.49 in./sec. at O'Brian's (2957 ft.)

For purposes of comparison and discussion, let us calculate the vibration intensity at the near side and the far side of the village for each of these four shots, and then arrange them in order from the strongest downward:

		NEAR SIDE OF VILLAGE	FAR SIDE OF VILLAGE
1.	Shot No. 143	1.36 in./sec.	0.19 in./sec.
2.	Shot No. 429	0.66 in./sec.	0.14 in./sec.
3.	Shot No. 75	0.65 in./sec.	0.09 in./sec.
4.	Shot No. 217	0.56 in./sec.	0.11 in./sec.

These four shots are the only ones we need to discuss in detail in relationship to safe limits for buildings. As far as can be determined, the remaining shots fell below these values and would not be of interest.

None of these vibrations exceeded the recognized standard in effect at that time, and stayed well below the recommendations of Anaconda's vibration monitoring consultants. That standard was a peak particle velocity of 2.0 in./sec. That limit was used almost universally from about 1949 until about 1977. It is still in effect in many project specifications whose primary purpose is to avoid damage to residences. Since 1949, millions of blasts have been monitored and regulated by that standard, and observed by many researchers, consultants and other professionals.

That standard was intended to prevent damage to buildings in poor condition, but did not give any special consideration to people (who are far more sensitive to sounds and vibrations than are the buildings they occupy). In recent years, more and more consideration has been given to the comfort and the peace of mind of people, and more severe restrictions have been placed on sources of sound and vibration. For example, from 1977, the federal Office of Surface Mining has required that open-pit coal mines restrict their blasting so as not to subject adjacent homes to particle velocities in excess of 1.0 in./sec. Most professionals agree that this is a reasonable restriction for a long-term large-scale blasting operation. Higher levels on a long-term basis would be alarming to most people and might have the potential for eventually causing threshold cosmetic damage in poorly constructed homes. This is not to be confused with <u>structural</u> damage, which requires much stronger vibrations (see Dick, Richard A., "A Review of the Federal Surface Coal Mine Blasting Regulations", Proceedings of the 5th Conference on Explosives and Blasting Technique, St. Louis, Mo., 1979.) Low-frequency vibrations in excess of 1.0 in./sec. have a low probability of causing threshold cosmetic damage in a low percentage of poorly constructed houses. Such threshold cosmetic damage is of no structural consequence, and would not usually be detected by an occupant, as it would usually require a carefully conducted professional survey before and after blasting to determine that it had occurred.

Thus, even though more recent regulations have required open-pit coal mines to restrict blasting vibrations to much lower levels than was the case before 1977, and even though Anaconda's metal mining operations are not under the jurisdiction of the Office of Surface Mining, their blasting operations conformed to the more recent limits imposed by OSM, with the exception of only 1 event out of 1400. To put this into perspective, most professionals agree that 90% conformance is expected, and that the exceptions should not exceed 150% of the limit imposed. These criteria were easily met.

The conclusions drawn from this analysis of the vibration recordings in and around Paguate are as follows:

1. None of the vibrations exceeded the standard limit in effect at that time.

2. None of the vibrations exceeded the limit recommended by Anaconda's vibration monitoring consultants.

3. Even though the Office of Surface Mining has required that this limit be reduced to only 1.0 in./sec. since 1977, and even though OSM has jurisdiction over open-pit coal mines only, Anaconda's blasting operations conformed to these more recent recommendations, within the normal meaning of such conformance for blasting.

4. Only a few of the closest houses near the east side of the village received vibration intensities in excess of 1.0 in./sec. and this happened only once out of 1400 recordings. The remaining houses received particle velocities ranging from 1.0 in./sec. to 0.19 in./sec. for this one strongest blast, and far less for the vast majority of the blasts.

5. Not even the strongest single blast of the 1400 recorded was capable of causing structural damage.

EFFECTS OF NATURAL FORCES ON THE HOMES AT PAGUATE

In order to understand fully the reasons for building conditions at any particular locality, one would have to be aware of the natural forces at work, as well as the type of construction. Some of the natural forces at work in this region are (1) earthquakes, (2) freezing and thawing, (3) total temperature cycle and thermal stress, (4) rainfall, saturation and erosion, (5) humidity changes and absorption, and (6) wind and storm.

A full discussion of these many topics would be prohibitively lengthy. Therefore, only a few general comments will be made in order to acquaint the reader with some of the considerations.

Earthquake Vibrations at Paguate. The following references have been reviewed in order to make an estimate of ground motions that have been transmitted to the village of Paguate during earthquakes.

1. "Seismicity of the Rio Grande Rift in New Mexico", New Mexico State Bureau of Mines and Mineral Resources, Circular 120, 1972, by Sanford et al.

2. "Instrumental Study of New Mexico Earthquakes, January 1968 Through June 1971", New Mexico State Bureau of Mines and Mineral Resources, Circular 126, 1972, by Toppozada, T.R. and Sanford, A.R.

3. "Earthquakes in New Mexico, 1849-1977", New Mexico Bureau of Mines and Mineral Resources, Circular 171, Sanford et al.

4. "Earthquakes in New Mexico, 1978-1980, Chapter 3, Updating of New Mexico Seismic Data", New Mexico Tech. Report prepared for DOE Low Temperature Assessment Program, 1981, Sanford et al.

As far as I am able to determine, no monitoring instruments were stationed in Paguate to record earthquakes. However, we can calculate the probable ground motions from the reported data and thus make a reasonable estimate of the vibration intensities in Paguate during these earthquakes. Referring to some of the earthquake data before 1962, we see that an Intensity of about IV (Modified Mercalli) would be estimated for Paguate, generating a particle velocity of about 0.63 in./sec. throughout the village. This motion would have been stronger for the majority of homes in Paguate than that induced by the blasting operations, although several of the closest homes to the mine received stronger motion from the blasting on one occasion.

There would be no reason to expect that any damage was caused by these earthquakes, considering the modest levels of vibration. However, as a matter of secondary interest, it should be noted that earthquakes can be expected to continue into perpetuity in this region, whereas the blasting operations have been terminated.

Temperature Effects. A review of weather records for this region shows that the annual range of temperatures typically is of the order of 100^{o} F, with a maximum range of about 118^{o} F sometimes occurring (from 16^{o} below zero to 102^{o} above zero).

Such temperature changes introduce very large stresses and strains in construction materials and in buildings. Even if freezing never occurred, the shrinkage and expansion associated with such temperature changes is damaging, and becomes more so for buildings where different materials are in contact (differential stress).

When the temperature drops below freezing, the damage is compounded. Materials which are not subject to freezing, and do not contain moisture will shrink as the temperature drops. Those materials which contain moisture will expand upon freezing, and will do so differentially because the freezing generally is confined to the near-surface zones. These natural forces are very damaging. In addition to the direct impact they have on the building itself, they adversely affect the soils and the foundations beneath the buildings, often causing pronounced swelling in the frozen state, then settlement when the thaw occurs.

Moisture Absorption. The area is relatively dry on a long-term basis, being subject to an average rainfall of about 10 inches (there was a maximum of 15.4 inches in 1969). However, occasional heavy rains are potentially very damaging to adobe construction. Even elevated humidity causes swelling of adobe, whether in the form of rain or not. Even if the adobe is not eroded by direct contact with the rain, adobe brick and adobe mortar can undergo dramatic changes in dimension with changes in moisture content simply by absorbing moisture from the air. The effect is proportionately worse as the clay content of the adobe increases. Conversely, heavy shrinkage occurs when adobe dries out.

Moisture changes have similarly adverse affects on clay foundation soils beneath structures. Severe structural damage can be expected when buildings are supported by expansive soils.

Wind. Wind damage is more easily identified since it happens quickly at a time when observers are aware of the force and can watch it at work. Many of the other natural forces work slowly and quietly and are unknown to the building occupants. The most common wind damage is that to windows or roofs, although violent winds can cause even more severe damage.

The continuous pressure of a wind has more capability of causing damage, such as the breaking of windows, than would the highly transient (short duration) pressure of an air wave from blasting, even though they might be at the same pressure. For example, if an engineer were selecting window glass to resist a certain pressure, he would select a stronger window if the pressure were a steady pressure such as wind, and he could select a thinner, weaker window if the pressure were transient, such as that from a sonic boom or a blast.

To give the reader some idea of the relative pressures involved, a typical surface mine blast would generate an air pulse which would have a pressure equivalent to a breeze of about 10 to 15 miles per hour.

HUMAN RESPONSE TO BLASTING EFFECTS

Upon hearing the startling secondary sounds often associated with blasting, such as rattling windows or doors, or the impact type of sound generated by an air wave against the roof or walls, etc., an observer will often judge that such sounds could only occur if something potentially harmful were taking place. And, indeed, the sounds might be identical if something harmful were taking place. Typically, the observer will then examine the house carefully and, of course, will discover certain cracks and other defects because these things exist in every house. Very often, such a person will then be genuinely convinced that blast damage has indeed occurred. He is not aware of the normal static (non-vibratory) forces which act on structures and bring about their typical condition.

One of the earliest studies of human response to motion was made by Reiher and Meister in 1931. Human subjects were tested for their response to steady-state vibrations in a 4 foot x 6 foot freely suspended platform. Among other things, it was observed that a standing person is more sensitive to vertical motion, and that a person lying down is more sensitive to horizontal motion perpendicular to the long axis of his body. All subjects were easily able to notice a motion which would be only about 1/100 of a potentially harmful level for structures.

Crandell (1949) reviewed this data and summarized his conclusions regarding the response of humans compared to that of structures. He concluded that the average person would consider a vibration to be "severe" at about 1/5 of the level that might damage structures. A great deal more data has been gathered in the ensuing years, confirming some of these basic observations, and adding certain refinements.

In the frequency range of typical blast vibrations of very short duration, the threshold of perceptibility to the motion does not appear to vary much with frequency, but it does vary considerably between individuals. In the case of small blasts, it varies considerably with duration. Although time dependence seems evident to an experienced observer of blasting phenomena, a quantitative relationship has not yet been established by controlled experiment. Moreover, such experiments would not be especially fruitful in the solution of blasting problems because other complex factors accompany the judgment of the observer. However, the results of tests with steady-state vibrations are of some benefit to the inexperienced observer. With motion alone, the results of experiments in response to steady-state vibrations are somewhat conservative. Depending on time duration of the transient vibration, the response may vary from about one-half of the response level to steady-state vibrations up to a level about equal with that to steady-state vibrations.

Thus, people are about half as sensitive to a motion of very short duration as to a steady-state motion, if the motion is not accompanied by sounds or other effects that could influence the human physiological or psychological response.

An objective response of a volunteer human to soundless, steady-state motion is not of sufficient help to explain the apparent extremes of sensitiviy exhibited by subjective homeowners responding to both motion and sound effects in their own homes from nearby blasting operations.

In actual practice, all rules for predicting motion response fall apart when sound effects accompany the motion and the motion is of short duration. In such instances, the average person forms a judgment based largely on his psycho-acoustic responses and is usually unaware of the important distinction between the characteristics of the motion alone and the sound effects that might accompany that motion. One type of sound effect is produced by a blast which generates a very loud noise at the source of the explosion. Such a blast is often regarded as severe and damaging even when damage did not occur and when motion was not perceptible. To the average layman, the loud noise itself is sufficient to prove severity. Similarly, a blast may be accompanied by an inaudible air wave that has sufficient energy to cause loose windows and doors to rattle. Motion may be imperceptible, but the building occupant can be expected to judge the intensity of the blast by what he heard. Simply stated, he thinks the building was subjected to strong vibrations because he heard the sounds of vibrating parts of the structure. He may be completely unaware that he actually felt no motion, andmay conclude that the motion was severe. When the listener judges that the house was shaking violently, he often concludes that damage must have been done, and proceeds to examine the house carefully for some sign of the expected damage. Ground vibrations, independent of air waves, may also cause similar sound effects in a building, and even an experienced observer may be unable to say whether the creaks and rattles were the result of ground vibrations or air waves. These sound effects vary considerably from one structure to another. An old frame building with loose doors and loose, double-hung windows may be very noisy, whereas an adjacent masonry structure with tight doors and tight casement windows may not rattle at all. Thus, observers in these buildings probably would react quite differently to the same blast, even though the ground motion and structural motion at the two locations might be the same.

Normally, responses to the various blasts on a project will vary widely among individuals, and any blast, no matter how small or how remote, may bring on a damage claim. It would be ideal if blasting could be held at a level that no one would regard as potentially harmful. In a heavily populated area, this does not seem possible.

Another problem involved in dealing with observations of structures, especially if a long time interval is involved, is that other forces are at work on all structures, and cracks continue to appear and grow from causes other than blasting. Even in the absence of blasting, a 30-year-old building is expected to have more cracks than a 10-year-old building, which in turn is expected to have more cracks than a new building.

APPENDIX A

The following appendix is provided for the benefit of those readers who might like to have additional background information to develop a greater depth of understanding of some of the items previously discussed.

CRITERIA FOR DAMAGE TO RESIDENCES

The study of blasting effects on residences has been stimulated primarily because of the adverse responses of persons occupying buildings in the vicinity of blasting operations. Because such a response is common to nearly all persons, this adverse reaction has been taking place since the beginning of commercial blasting operations and has stimulated a great deal of investigation into the evaluation of blasting effects. The following comments provide a brief review of some of the publications and researches most often quoted in developing regulations, specifications, or other controls and limits.

ROCKWELL, 1927.

Following World War I, increased building demands in the U.S. brought about an expansion of the quarrying industry, requiring an increase in blasting activities in occupied areas. This activity stimulated an increasing number of blast damage claims and an increasing interest in the subject by technical investigators. One of the first reports on blasting effects reported in this country was made in 1927 by Rockwell (see reference list, Rockwell, 1927). Rockwell concluded that quarry blasting as normally conducted would not produce damage to residential structures if they were more than 200-300 feet from the quarry. It should be noted that there is a much wider choice of equipment and methods available to quarry operators today, so that same statement would not necessarily be true today, although generally so.

BUREAU OF MINES, 1942.

Growing complaints and litigations eventually stimulated a research effort headed by the Bureau of Mines to investigate the problem and to develop suitable criteria to avoid damage. The research continued through the 1930's, was completed in 1940, and led to the publication of Bulletin 442, in 1942 (Thoenen and Windes, 1942). Despite the adverse response to blasting, and the common damage claims associated with it, the Bureau investigators were unable to find damage generated by quarrying operations. This fact raised a difficulty in developing criteria, that is how to "prevent" something that wasn't happening. However, by designing and using mechanical shaking devices attached to various parts of houses, they were able to reach some conclusions about vibration damage to small structures, and offered to the public and the industry the first published recommendations to limit seismic effects. However, these recommendations quickly became obsolete as more representative case histories became documented through the work of Crandell and of subsequent researches.

CRANDELL, 1949.

In 1949, F. J. Crandell reported results from a study which involved actual damage to structures from blasting operations, in which observations were made of buildings shceduled for demolition that were subjected to high intensities of vibration before being demolished. In reporting his data, Crandell used a term called "Energy Ratio", which happens to be proportional to the square of particle velocity, the term most commonly used today to express the damage potential of blasting vibrations.

According to Crandell's vibration damage data, an Energy Ratio of 3.0 was safe (equivalent to a particle velocity of 3.3 inches per second), between 3.0 and 6.0 was a caution zone, and above 6.0 was a danger zone (equivalent to a particle velocity of 4.7 inches per second).

LANGEFORS ET AL, 1958.

In 1958, another report of damage studies appeared (Langefors, Kihlstrom and Westerberg, 1958). These investigators had obtained a large amount of data for blasting in hard rock at very close distances. Some damages occurred and were reported as follows:

2.8 in./sec.	No noticeable damage.
4.3 in./sec.	Fine cracking and fall of plaster.
6.3 in./sec.	Cracking.
9.1 in./sec.	Serious cracking.

EDWARDS AND NORTHWOOD, 1960.

In 1960, Edwards and Northwood reported a damage study on six residences. Three of the houses were located on a soft sand-clay material, and three were located on a well consolidated glacial till. Twenty two blasts were detonated at progressively smaller distances until damage occurred. The authors concluded that damage was more closely related to particle velocity than to displacement or acceleration, and that damage was likely to occur with a particle velocity of 4 to 5 inches per second. Including a factor of safety, they recommended a limit of 2.0 in./sec. to avoid damage.

VARIOUS STATES AND AGENCIES, 1949-1960.

Several states and organizations adopted vibration limits during this period from 1949 to 1960. For example, the State of Pennsylvania adopted 0.03 inches of displacement as a safe blasting limit. New Jersey and Massachusetts adopted an Energy Ratio of 1.0 (particle velocity of 1.92 in./sec.), based on Crandell's work, including a factor of safety. Agencies such as the U.S. Army Corps of Engineers and the New York State Power Authority specified a limit of an Energy Ratio = 1.0 for various construction projects.

BUREAU OF MINES, 1959-1972 - BULLETIN 656.

The U.S. Bureau of Mines also began a new seris of investigations, beginning in 1958. These culminated in the publication of a series of Reports of Investigations, and finally in the publication of Bulletin 656 in 1972 (Nicholls, Johnson and Duvall, 1972). Their report included a review of the major damage data from the previous studies mentioned above, and included data from an additional 171 blasts at 26 different sites. Their major conclusions were:

1. The damage potential relates more closely to particle velocity than to acceleration or displacement.

2. A limit of 2.0 in./sec. should not be exceeded for residences if the probability of threshold damage is to be kept low.

3. People are very sensitive to sound and vibration, and ground motions would have to be kept below 0.4 in./sec. if complaints and damage claims are to be kept low.

4. Air blast does not contribute to damage in most blasting operations. The control of ground vibration to safe levels automatically limits airblast overpressures to safe levels.

5. Regarding the delay intervals used in initiating sequential detonations, the report states that "the maximum charge weight per delay was considered as the charge weight for each shot" and "the vibration

levels from blasts using 5 millisecond delays did not differ appreciably with those from shots with longer delays and were included in the analysis" (pg. 41).

BUREAU OF MINES, 1974-1980.

Many persons associated with the use of explosives were well aware that vibration levels of 2.0 in./sec. generated verv strong adverse reactions from homeowners. Sounds of rattling and shaking, and the accompanying fear of property damage, generate strong public opposition at these levels. As a result, many quarry and mine operators have always kept vibration levels below this limit, even though it may have been permitted by regulation. However, in recent years, many of the regulatory agencies have become more sensitive to the public response and have imposed stricter limitations to reduce the fear of damage, often regarded as actual damage. For example, in 1957, the State of Pennsylvania had changed its regulation (from a displacement limit of 0.03 inches) to permit a particle velocity of 2.0 in./sec., but in 1974 adopted more stringent limits because of pressures from citizens groups.

The U.S. Bureau of Mines maintained an interest in different aspects of the general subject of blasting operations, including ground vibrations, airblast, and certain other topics not directly of interest to this case. From 1974, the Bureau undertook additional studies of ground vibrations and airblast. Several of their Reports of Investigations appeared in print in 1980. One of particular interest is RI 8507 (Siskind et al, 1980), primarily because it recommends a revision in criteria to more stringent levles, especially for low-frequency vibrations. In these recommendations, the previously suggested limit of 2.0 in./sec. was retained for high-frequency vibrations (above 40 Hz), but the suggested limit was reduced to 0.75 in./sec. for drywall construction and to 0.50 in./sec. for wet plaster construction in the frequency range of 4 to 12 Hz. Further, there is a suggestion for a displacement limit of 0.03 inches below 4 Hz, and of 0.008 inches between 12 and 40 Hz.

The authors point out that ordinary human activity inside a residence will often generate particle velocities of 0.5 in./sec. Thus, the effect of their more restrictive recommendations is to keep external sources of vibration to the same damage potential as certain internal activity.

RI 8507 is based largely on statistical and probability analyses of old data, including some which had been rejected previously by the Bureau of Mines authors of Bulletin 656 because of the questionable validity of some of the data. Relatively little new damage data was obtained. However, it is generally recognized that most light-weight frame residences do respond in the manner described in RI 8507, and that there is a greater potential for damage at the lower frequencies. This concept has been described in many earlier publications, including the Bureau Bulletins of 1942 and 1972. The theories behind this response have been discussed in publications for at least 100 years.

REFERENCES

PROJECT SPECIFICATIONS AND REGULATIONS

1942 - Thoenen and Windes, "Seismic Effects of Quarry Blasting" Bulletin 442, U.S. Bureau of Mines

1949 - Crandell, F. J., "Ground Vibrations Due to Blasting and Its Effect Upon Structures", Journal Boston Society of Civil Engineers, April, 1949

1958 - Langefors, Kihlstrom and Westerberg, "Ground Vibrations in Blasting", Water Power, February, 1958.

1960 - Edwards and Northwood, "Experimental Studies of the Effects of Blasting on Structures", The Engineer, Sept. 30, 1960.

1970 - Oriard, L. L., "Blasting Operations in the Urban Environment", AEG National Meeting, Washington, D.C., Bulletin, 1972.

1971 - Nicholls, Johnson and Duvall, "Blasting Vibrations and Their Effects on Structures", Bulletin 656, U.S. Bureau of Mines.

1972 - Hendron and Oriard, "Specifications for Controlled Blasting in Civil Engineering Projects", Proc. First North American Rapid Exc. and Tunneling Conference.

1974 - Wiss and Nicholls, "A Study of Damage to a Residential Structure from Blast Vibrations, ASCE, 1974.

1980 - Oriard and Coulson, "TVA Blast Vibration Criteria for Mass Concrete", ASCE National Meeting, Portland, Oregon, 1974.

1980 - Tart and Oriard, "Blast Damage Criteria for a Massive Concrete Structure", ASCE National Meeting, Portland, Oregon.

1980 - Siskind, Stagg, Kopp and Dowding, "Structure Response and Damage Produced by Ground Vibrations from Surface Mine Blasting", RI 8507, U. S. Bureau of Mines.

1982 - Oriard, L. L., "Blasting Effects and Their Control", Underground Mining Methods Handbook, SME of AIME, 1982.

PERSPECTIVE ON DAMAGE CRITERIA AND LEVELS OF DAMAGE

Previous comments in this report have been directed primarily to those studies and recommendations which have dealt with an effort to determine the greatest sensitivity of the poorest quality residences. The purpose of most of these studies has been directed to establishing criteria to prevent either threshold damage, or to prevent damage claims and complaints under the most unfavorable of conditions. Unfortunately, it is a common conclusion by many persons that any and all types of damage to structures might occur if vibrations exceed the conservative limits recommended. An experienced observer will realize that this is not the case at all. A more careful review of the available damage data will illustrate the fact that vibrations which exceed the "standard" recommendations do not normally cause damage, nor is such threshold damage of significance structurally. One illustration of this fact can be found in a study in 1969 in which the Bureau of Mines participated in a test program sponsored by the American Society of Civil Engineers (Wiss and Nichols, 1974). A 33-year-old residence was subjected to increasing levels of blast loading until damage finally occurred. A series of ten blasts was detonated near the residence. Through the first 8 blasts, the peak particle velocity had reached nearly 7 in./sec., but no damage occurred. The vibrations from test 9 opened 3 new cracks in gypsum wall board in an upstairs room after ground motion beside the house reached a peak particle velocity of 22.2 in./sec., over 11 times the "safe" levels recommended in Bulletin 656 and correspondingly higher than the more conservative limits suggested in RI 8507. There was no structural damage to the house, only the minor cosmetic damage in the gypsum wall board. In fact, the authors of the study report that variations in the widths of existing cracks were greater during intervals when blasting was not done than during periods when blasting occurred.

This writer has had many similar experiences. He has observed many residences and other small non-engineered buildings subjected to peak particle velocities in the range of 5 to 15 in./sec. without incurring damage of any kind. Although this writer has examined many hundreds of buildings before, during or after blasting operations, he has not yet had the experience of observing one where damage occurred below 2.0 in./sec. Such an occurrence must be considered unusual, not the norm.

These observations have not been limited to new, modern home construction. The writer has examined small residences (adobe, stone rubble, bamboo lath, filled-wall, etc.) in many parts of the world, including the United States, Canada, Mexico, Central America, South America, Europe, the Middle East, the Orient and the Pacific Islands. He has observed various construction methods, and the effects of various static and dynamic forces on these structures.

One case involving old buildings subjected to blasting took place in Monterey, California, when a large rock cut was excavated for a freeway between two of the oldest buildings in California, dating from the Spanish administration in the 1700's. These two old buildings were subjected to blasting vibrations with peak particle velocities of the order of 2.3 in./sec. and did not sustain even threshold damage, despite their deteriorated condition. (see Photo) (one is adobe).

Much higher vibration intensities were received by approximately 100 homes in a small town on another occasion when blasting approached within just a few feet. The blasting operations generated peak particle velocities in the range of 5 to 30 in./sec. at the nearest portions of many of these buildings. No building damages were reported or observed (see Photos).

VIBRATIONS INDUCED BY BUILDING OCCUPANTS AND NEARBY TRAFFIC

Technical investigators have long been aware of the deceptive nature of blasting vibrations because of the sound effects that accompany them. Observers tend to have an exaggerated perception of blasting. In order to provide comparative data, the Bureau of Mines and others have measured the vibrations induced by other activities. A few examples appear in the literature.

Bulletin 442 of the Bureau of Mines (1942) reports several sources of vibration in addition to blasting. A brief summary is given below. For more details, the reader is referred to the Bulletin.

14,000 lb. truck, solid tires: (at 63 ft.)	0.0069 in. (displacement)
8,500 lb. truck, pneumatic tires: (63 ft.)	0.0026 in.
motor vibration:	0.0019 in.
man jumping a few inches:	0.0068 in.
blasting, 1.13 pounds explosive. (715 ft.)	0.00015 in.
blasting, 17,250 lbs. explosive.(1810 ft.)	0.033 in.

Of eleven quarry tests, only two gave more displacement than the heavy truck.

Bulletin 656 of the Bureau of Mines (1972) gives additional data of similar character.

walking:	0.37 in./sec.
door closing:	0.06 in./sec.
jumping:	5.0 in./sec.
heel drops (rising on toes and dropping back on heels):	3.5 in./sec.

Report of Investigations 8507 reports the following:

walking:	1.49 in./sec.
nail hammering:	3.81 in./sec.
sliding glass door:	0.27 in./sec.
slamming entrance door:	1.29 in./sec.
heel drops:	5.84 in./sec.
jumping:	10.1 in./sec.
mine blasts:	1.37 in./sec.

An experienced technical investigator is well aware that typical blasting vibrations, generated by controlled operations at moderate-to-large distances do not generate more vibration than many common activities, although this fact has not generally been perceived by the public. In fact, it goes contrary to common intuition, and is commonly rejected out-of-hand as being untrue by most untrained persons. Many persons will riducule such statements as being biased and untrue, even when the data is available to prove the validity.

TIME CORRELATIONS BETWEEN DAMAGE, BLASTING AND OTHER CAUSES

The average person has had no reason to study structures nor the earth sciences, and is not aware of the various forces which act in silence on a structure, causing it to deteriorate with time. Proof of the lack of awareness of these forces is the frequency with which the average person asks the question, "If it wasn't blasting which caused these cracks, what could it have been?" This is one of the most overworked questions heard in explosives engineering. Yet, the fact that such a question could be asked demonstrates how formidable is the task of public education on this topic. Of course, there is a long list of factors besides blasting "that it could have been".

The above question is usually raised because of some apparent time correlation between blasting activity and the building crack (or other defect). There is no doubt that an apparent time correlation has a strong psyochological impact on a person's judgment. However, many forces are usually involved and the static forces are not usually recognized.

The commonly held conclusion is that one needs only to make an inspection of the structure in question before and after the blasting project. If the conditions are different at the time of the latest inspection, it is assumed that any observed change was the result of stressed induced by the blasting, unless it is recognizably impossible to relate the damage to vibration. Unfortunately, there can be considerable differences of opinion as to what is recognizably impossible. Claims files are full of items that the majority of technical consultants are aware could not be correlated with vibrations. Yet, some persons will accept allegations of this type if the feature of interest seems to have developed during the time period in question. Of course, such conclusions are reinforced if the "damage" seems to be the kind of effect that could be generated by vibrations of sufficient intensity. The most common of these are building cracks of various types. But merely because it is possible to generate cracks by vibrations does not mean that cracks which occur during the time of blasting operations have any relationship whatever to the blasting.

The most dramatic type of case is that where older homes in relatively good condition then undergo damage during a relatively short period of time during which blasting is taking place. But even in that case, time correlation, or <u>apparent</u> time correlation, may be quite deceptive and irrelevant. If there is not sufficient intensity of vibration to account for the damage, it clearly must be caused by something else, even though the cause may not be immediately obvious. This can be illustrated by reference to a case history, where this writer was retained by the administration of a small city to investigate extensive residential damages in the general vicinity of a quarrying operation. Many homes were damaged and some of the damage was quite serious. It was well documented that much of this damage had occurred within a period of about a year to homes that were about 25 to 30 years old at the time. These houses were about a mile from the quarrying operation. The quarry had been operating intermittently for many years. It had been idle for some time, but undertook blasting operations for a portion of the year in question. There was documented evidence that a considerable amount of damage occurred during the time of the blasting operations.

Virtually every home owner who had suffered any damage was firmly convinced that the quarrying operations were to blame. However, certain important facts were noted during the investigation that did not support this conclusion. For example, houses with no damage at all were found next door to houses that had suffered very serious damage. Also, another housing development in the opposite direction was located directly in front of the quarry at very close distance, yet none of these houses had suffered any damage at all. Calculations showed that the amount of vibration at the area in question could not be capable of causing damage. The only "proof" of damage from blasting was that they both took place during the same period of time. Of course, everyone asked the same question, "What else could have caused the damage? Obviously, it must have been blasting."

It turned out that hundreds of homes in this general region had suffered damage during this period of time, some of them many miles from the small quarry. It happened during a period of extremely dry weather. This one residential area was built on a fill where the water table normally was found very close to the ground surface. During this dry weather, the water table dropped, the soils dried out, shrunk and settled. There was as much as 6 inches difference in soil settlement between the front and back of some houses.

There were additional facts disclosed by the investigation. In all, it was clear to an experienced technical investigator that there was no correlation between the blasting activities and the extensive damage in this residential area despite the universal opinion of the homewowners to the contrary. Once the technical facts were made known to the city administration, the case was immediately closed.

Static Forces

Of course, there are many static (non-vibratory) forces which act on buildings to generate cracks and other defects. These may be generated either internally or from external sources. Many internal stresses are developed by changes in moisture and temperature, seasoning of lumber, drying and curing of plaster, concrete or adobe, changes in application of internal heat, aging, loss of Coulomb friction, changes in external soil conditions, drainage, weather, vegetation, etc., as well as the gravitational loads induced by the weight of the structure itself and all of the dead loads added by furnishings and persons inside the home.

The more common dynamic stresses are induced by human activity within the home and wind pressures against the exterior surfaces of the building, although others may be found in certain homes in the vicinity of industrial activities, etc. Of course, earthquake vibrations would be a matter of interest in seismically active areas.

As in the case history described above, expansive soils are one of the most serious problems for small buildings, especially those that are not engineered. It has been estimated that such soils inflict at least $2.3 billion in damage to buildings, roads, pipelines and other structures each year. Damage due to expansive soils results from shrinking and swelling of the soil in response to changes in the moisture content. The moisture changes may occur naturally, or may be influenced further by the landscaping and yard maintenance practices of the building occupant.

Mathewson et al (1980) provide a description of a study of over 400 brick veneer, single-family homes located in three cities in Texas, in which the authors investigated the effects of expansive soils on building damage. Sixteen independent variables were evaluated. A few of the more important included:

1. Age.

2. Vegetation (amount and distance from house).
3. Depth of the active soil zone.
4. Rainfall ratio.
5. Plasticity index.
6. Yard maintenance.

Because of the southern location, it was not necessary to consider the additional influence of freezing and thawing, a problem in most areas in the continental U.S.

The displacement associated with the blasting operations in Paguate appeared to range from less than 0.0001 inch (one ten thousandth of an inch) to as much as 0.01 to 0.02 inches (one to two hundredths of an inch). In contrast, there are many natural strains of greater magnitude to which houses are subjected. For example, shrinkage or expansion of wooden timbers frequently causes changes in dimension of the order of 1/4 to 1.0 inch, as moisture content changes from season to season. Also, all materials are subjected to changes in dimension from changes in temperature, as well as moisture, and each material has its own characteristic coefficient of expansion. Thus, not only do these materials undergo stresses, but adjacent materials undergo different changes and this difference causes very high stresses where the materials meet.

Water is commonly employed in the preparation of certain building materials, such as concrete, plaster, stucco and adobe. When these materials cure and dry, the water is evaporated, and there is a change in the volume (dimensions) of the material. A poorly formulated adobe can change volume by as much as 1/3 of the original.

Architects, engineers, and most experienced builders are aware that there are many natural causes of cracks in buildings. As early as 1925, one could find publications tabulating some of the common causes of cracks. The Architect's Small House Service Bureau of the United States published a list of 40 reasons why walls and ceilings crack (The Small Home, Vol. 4, No. 8, 1925).

A careful study of buildings shows that many cracks not only appear and grow larger as the building gets older, but that some cracks expand and contract on a relatively short-term basis with changes in temperature and moisture. In one case, this writer measured small changes in the widths of cracks between morning and afternoon (due to temperature changes) in a plaster applied over a new type of insulation.

In order to develop those same strains by vibration, it would be necessary to generate vibrations that would seem catastrophic to occupants of a building. For example, refer to the section of this report titled "Perspective on Damage Criteria and Levels of Damage". Here, there is mention of the damage study jointly conducted by the Bureau of Mines and American Society of Civil Engineers, where an old home was subjected to vibrations intensities up to 22.2 in./sec. The study report states that variations in the widths of existing cracks were greater during intervals when blasting was not done than during periods when blasting occurred.

APPENDIX B

PHOTOGRAPHS

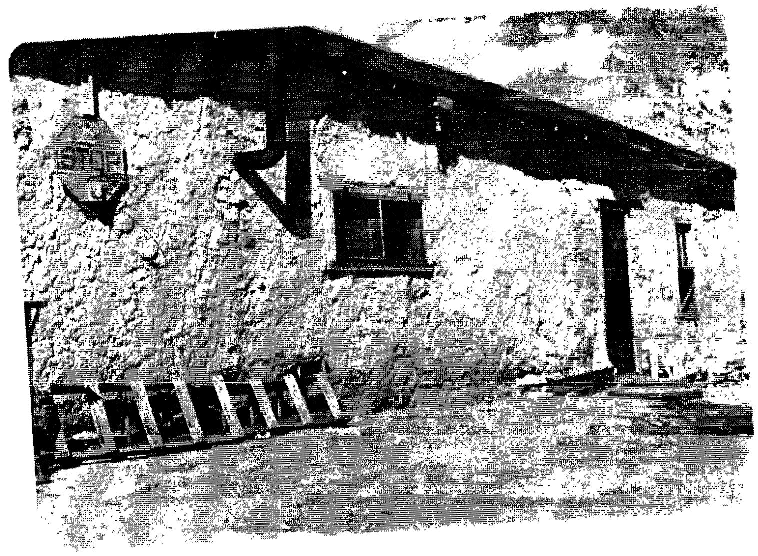
The following photographs were selected as being representative examples of the types of conditions found in Paguate, in neighboring villages, and in other areas in New Mexico. In addition, the appendix contains some photographs illustrating blasting operations taking place directly adjacent to various types of buildings where excavation had to be conducted in other rocky regions of the country.

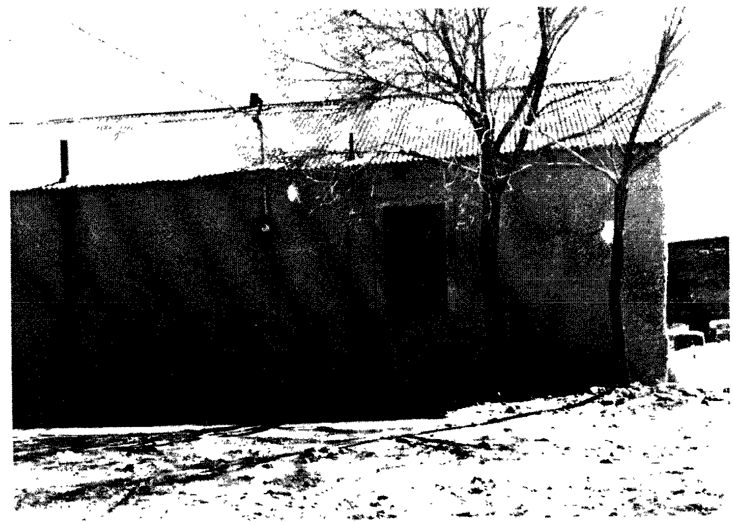
PHOTOGRAPHS OF PAGUATE

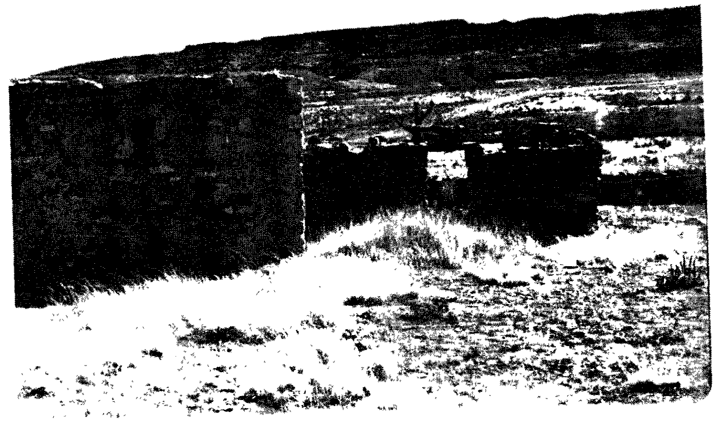
The following 12 photographs show typical building conditions in Paguate for a variety of types of construction.

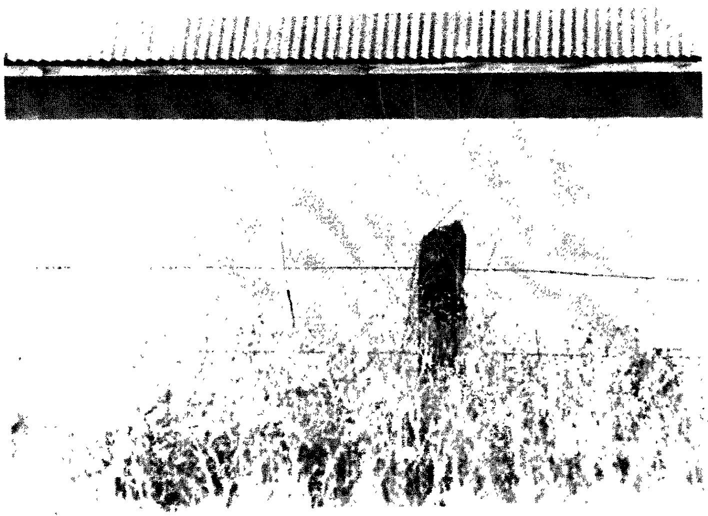
In general, the photos begin closest to the mining operations and proceed to greater distances.

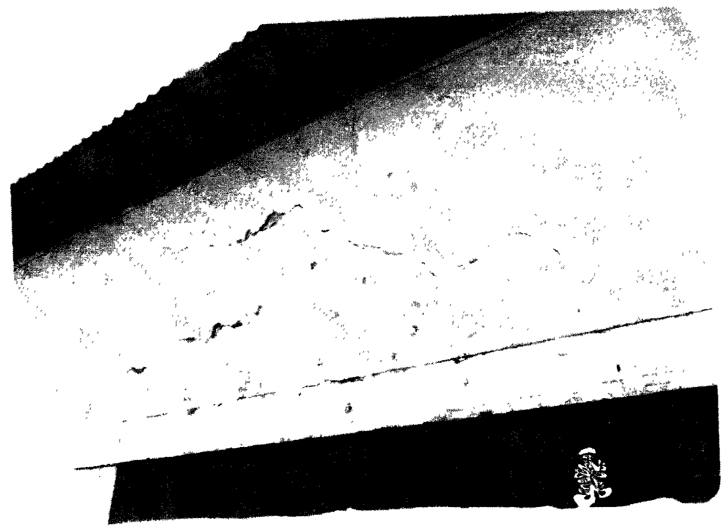
The last two photos show the interior of an adobe structure on the mining property.

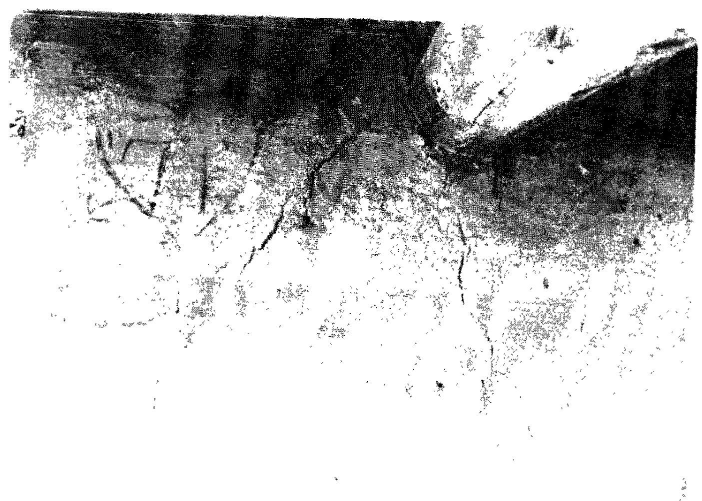


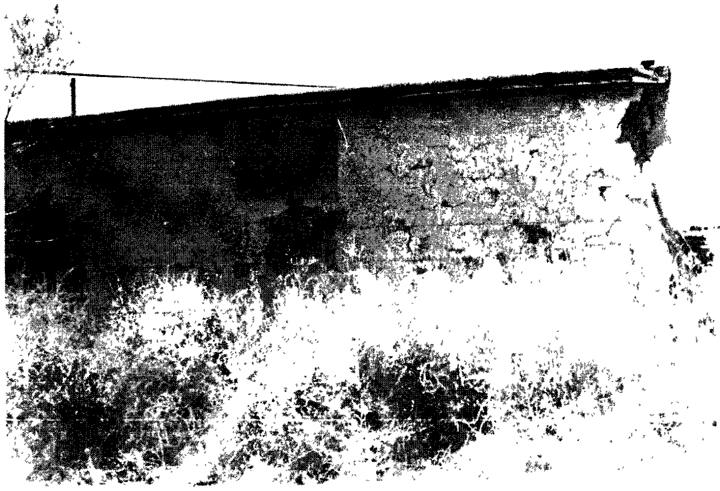


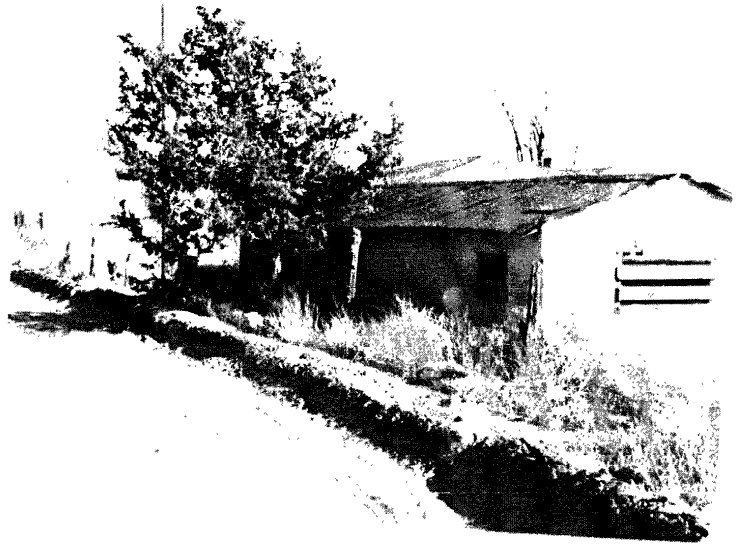


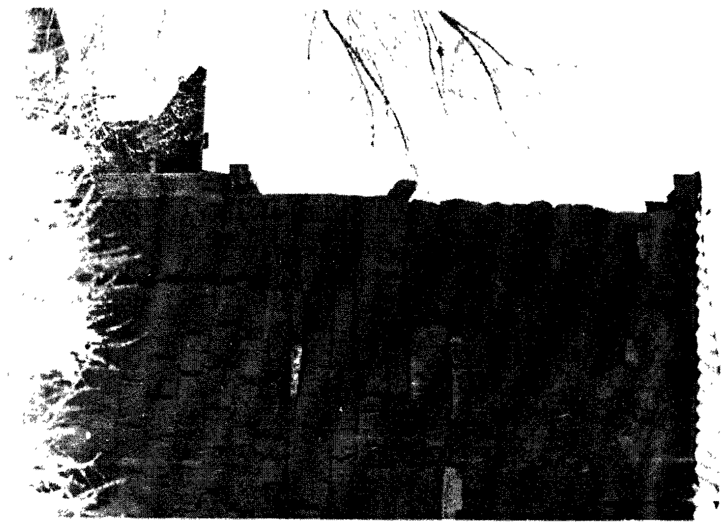






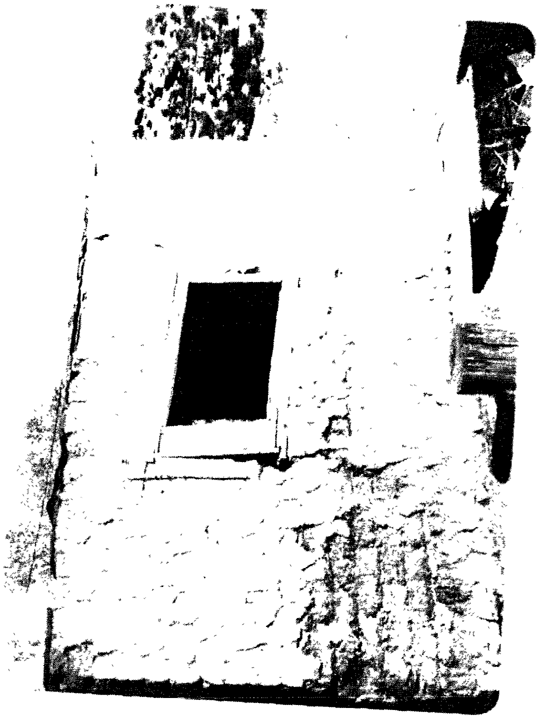


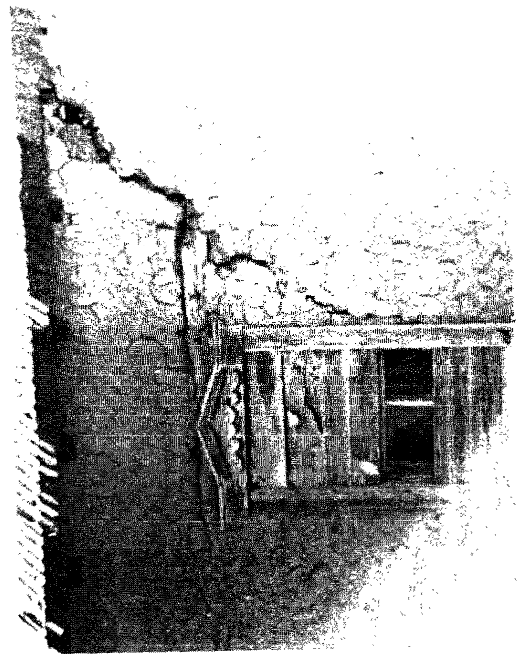


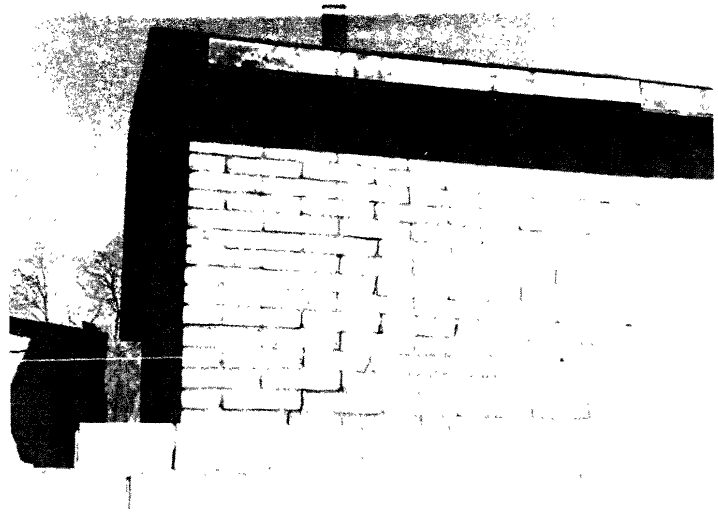


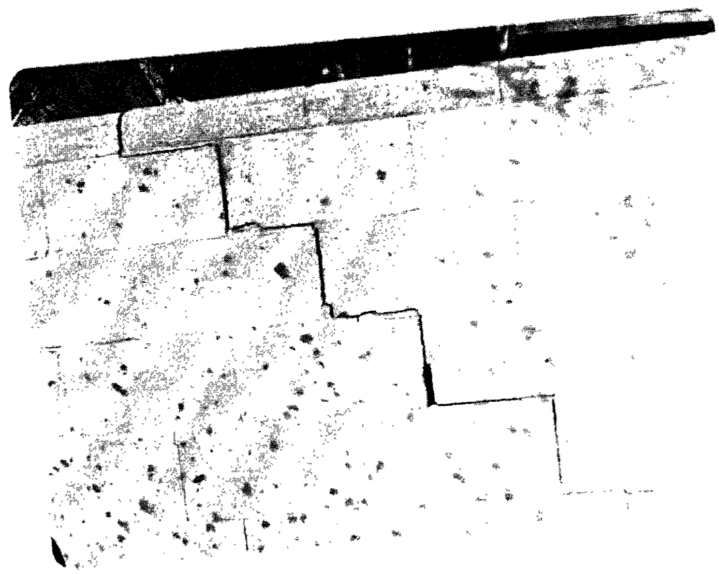
PHOTOGRAPHS OF OTHER AREAS IN THE REGION THAT ARE NOT NEAR THE MINING OPERATIONS.

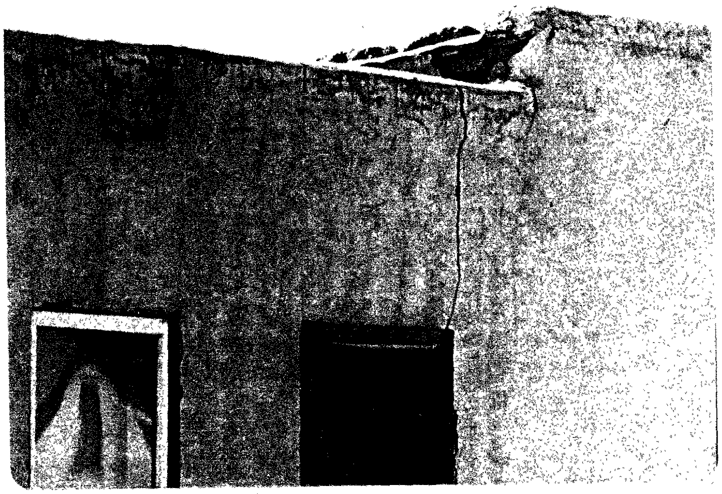
The following 18 photographs show representative conditions of buildings in the same general region, but far removed from the mining operations. The photos were selected to show a wide range of construction types. No matter what construction materials or designs were used, various types of cracking and deterioration are common everywhere.

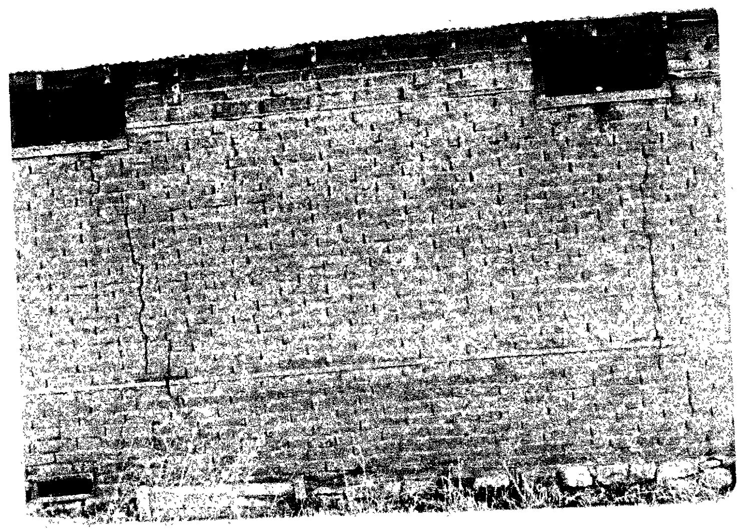


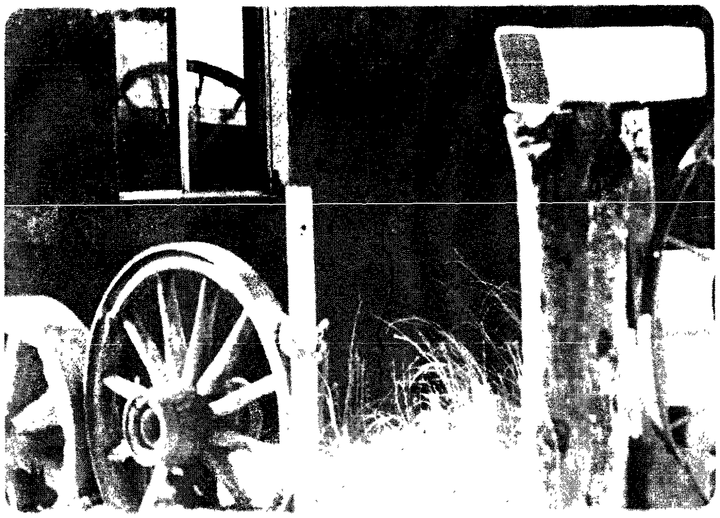


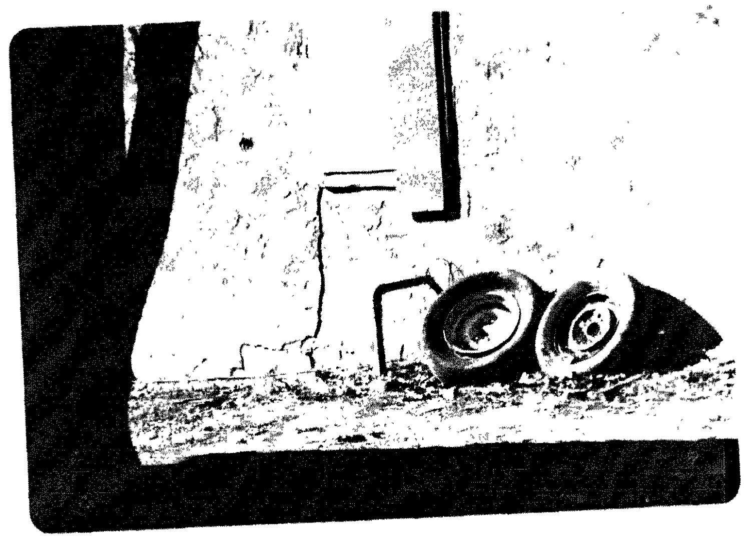


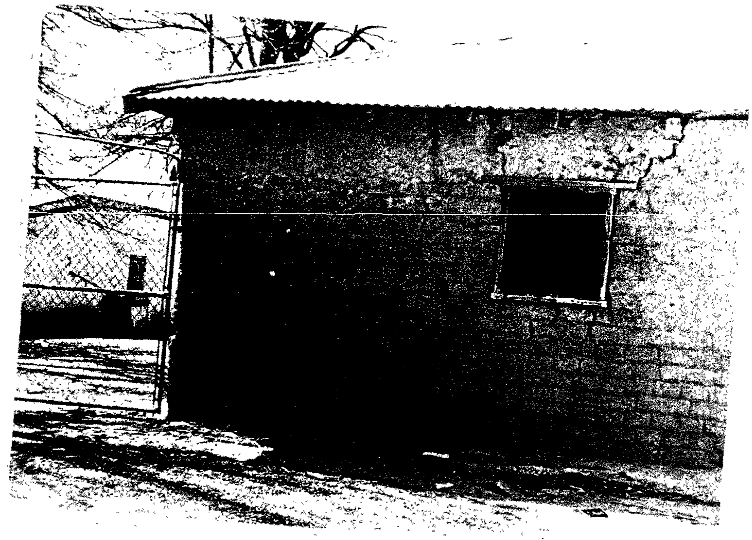
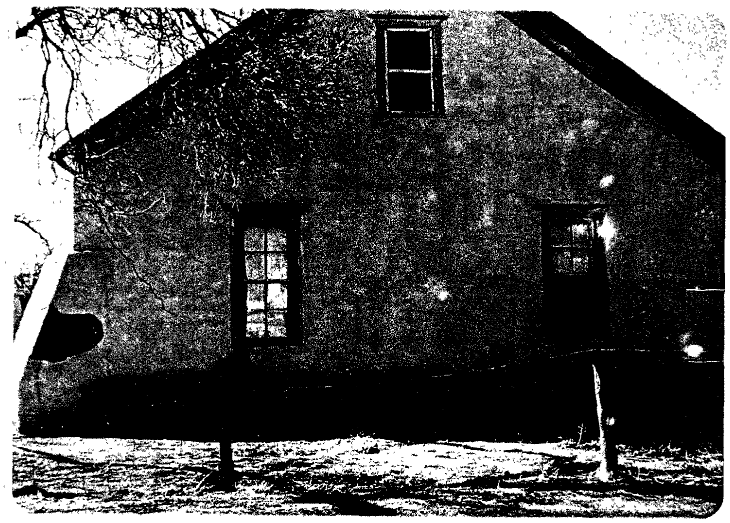


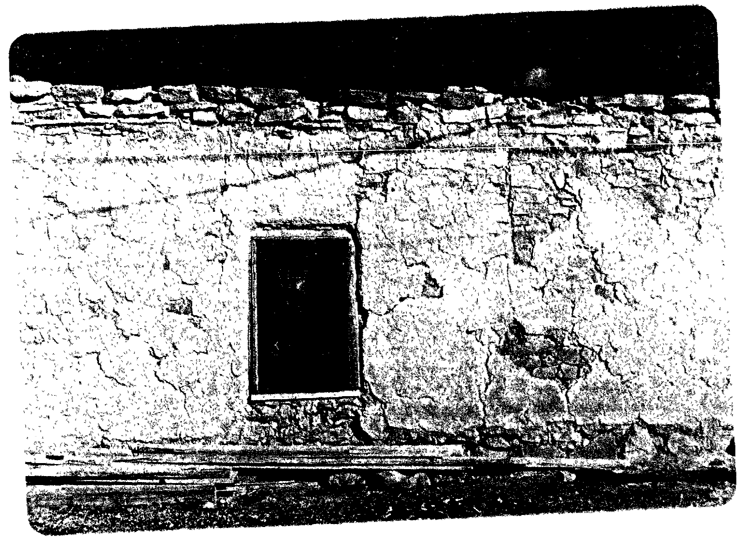


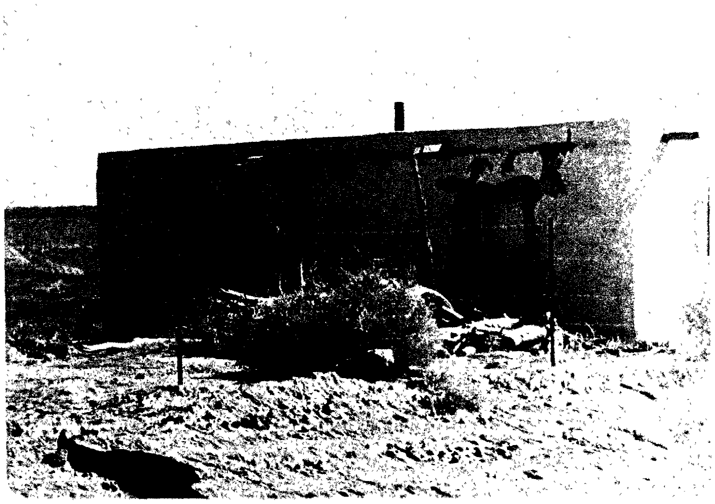






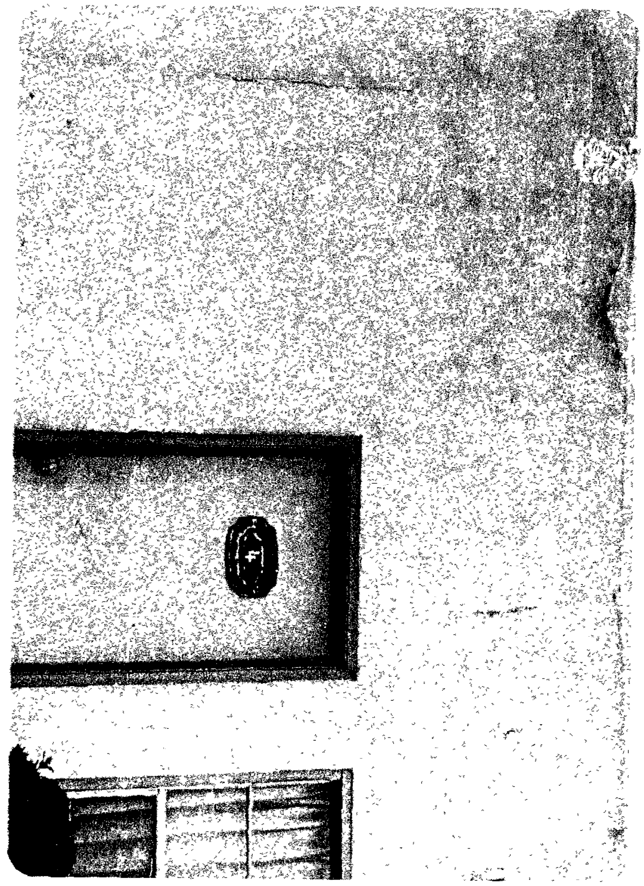


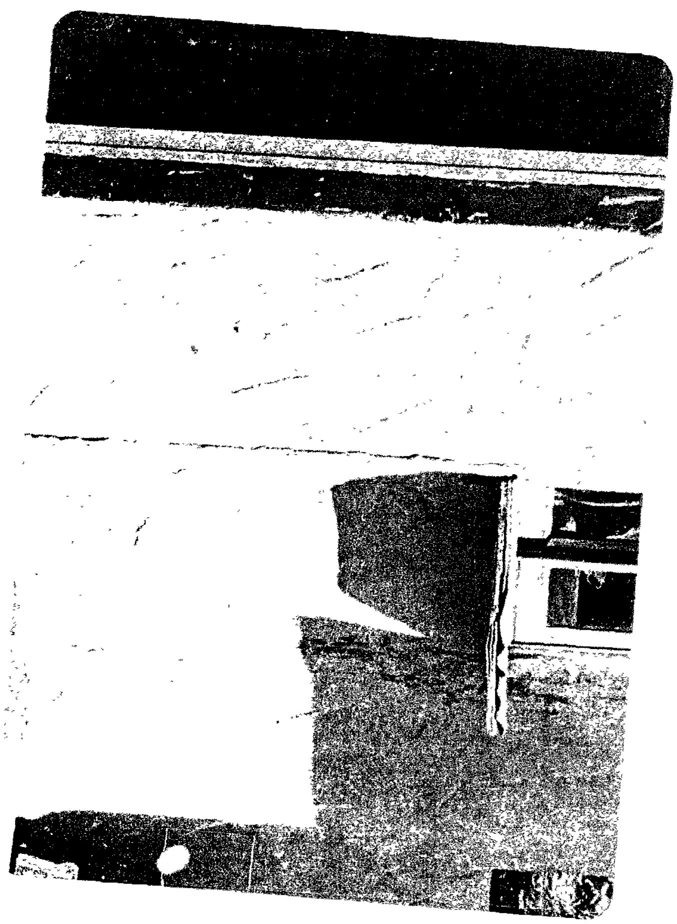


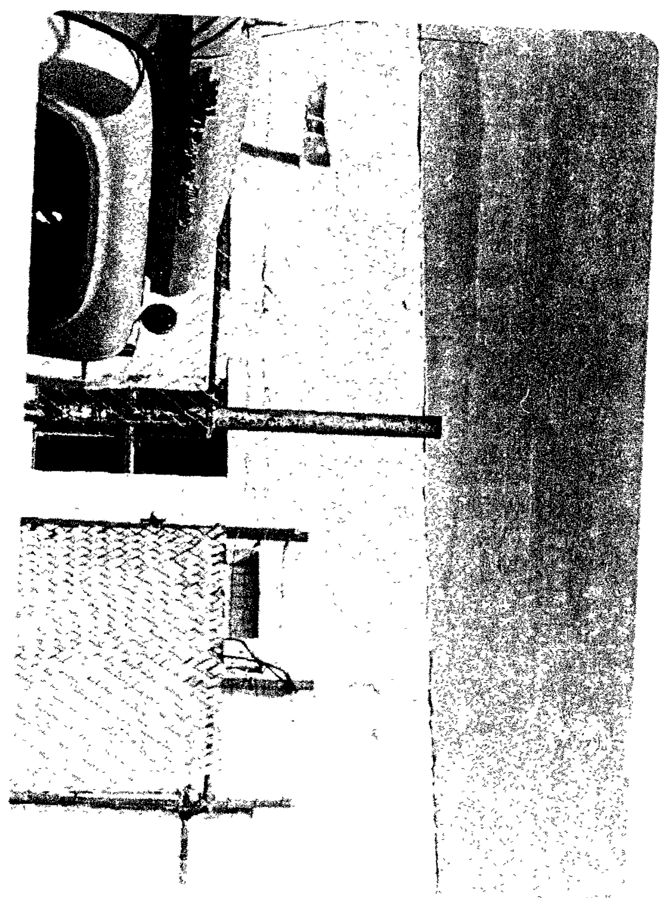
PHOTOGRAPHS OF WEST ALBUQUERQUE

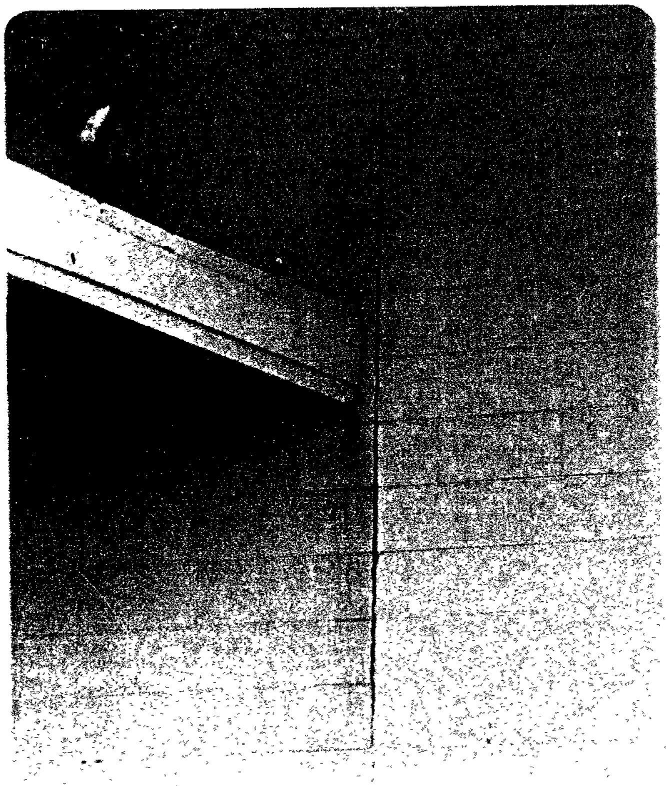
A visitor to Albuquerque would note that the same types of cracks and deterioration that were found in Paguate and neighboring villages can be seen everywhere, whether for residential or commercial construction.

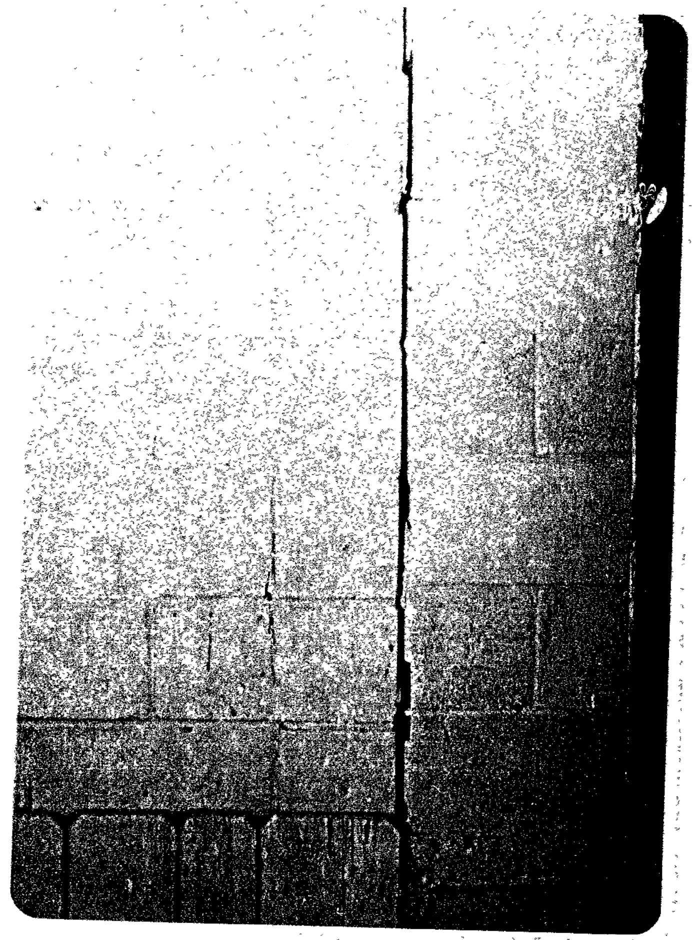
The following six photos show typical cracks as seen in commercial buildings in West Albuquerque.

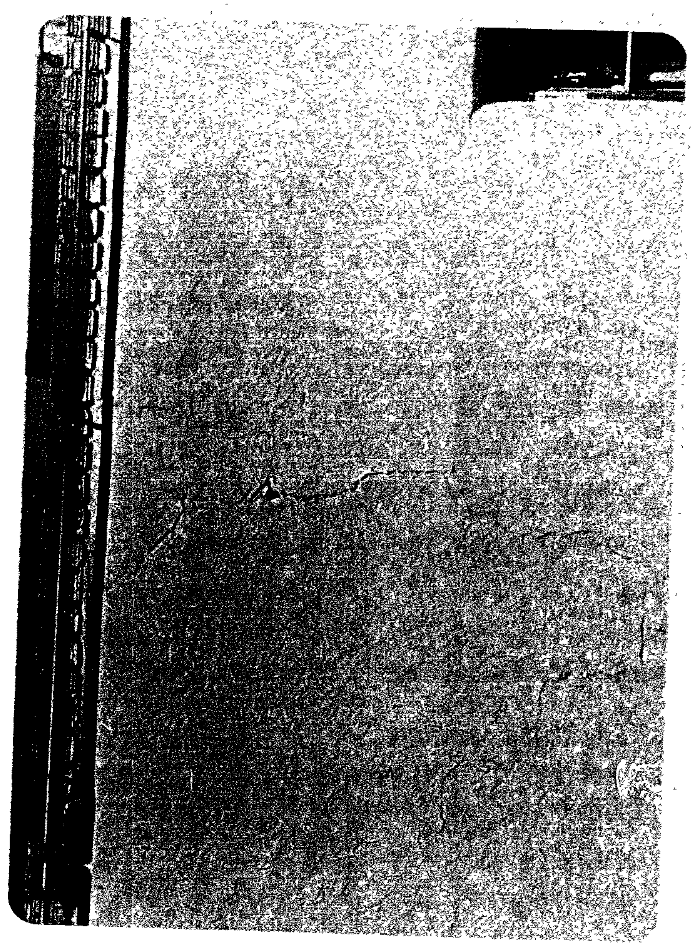








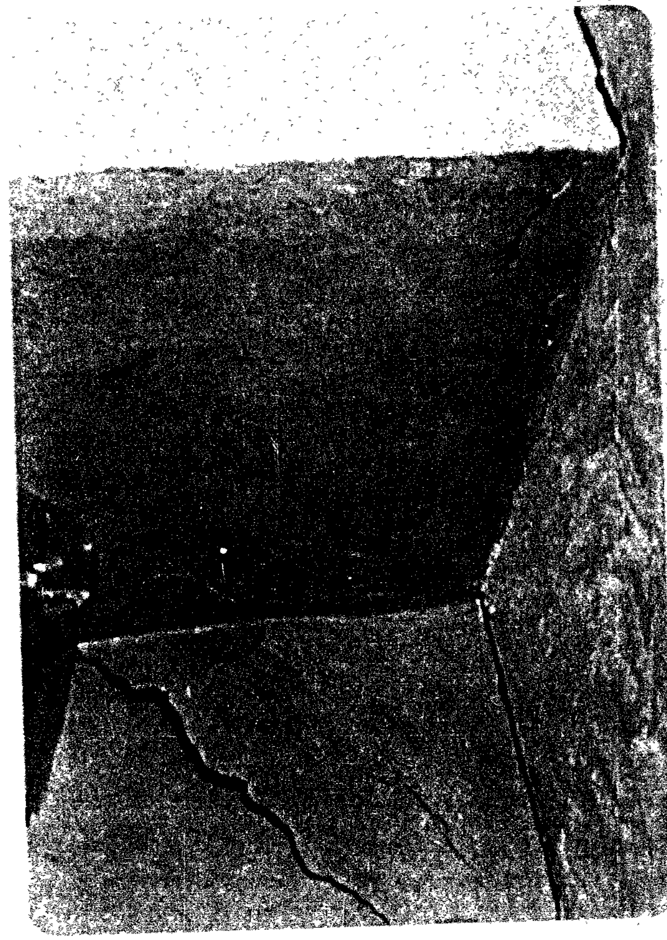


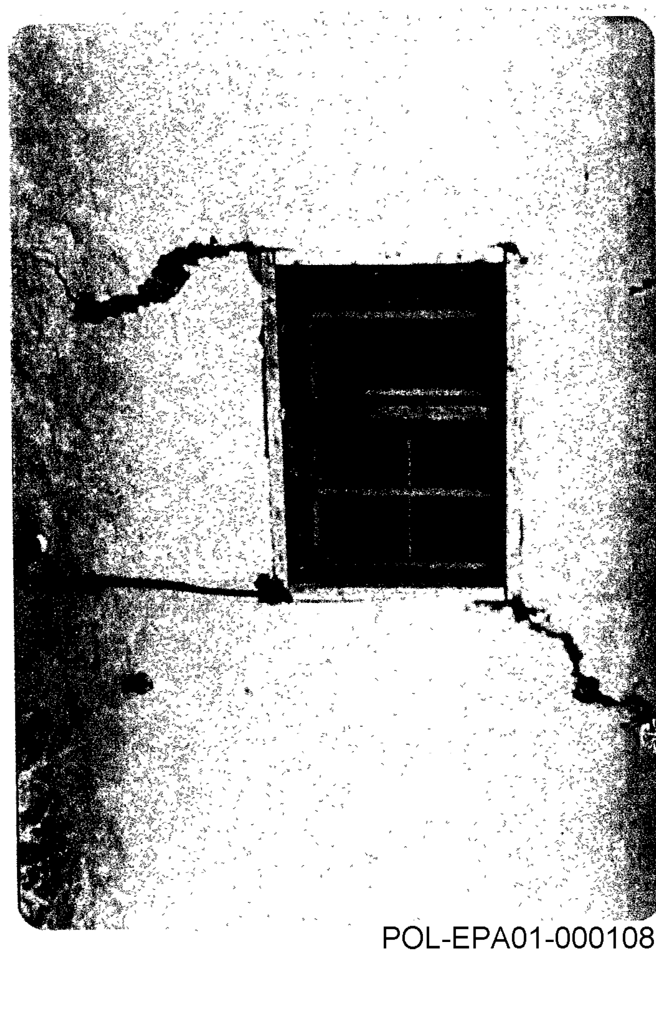


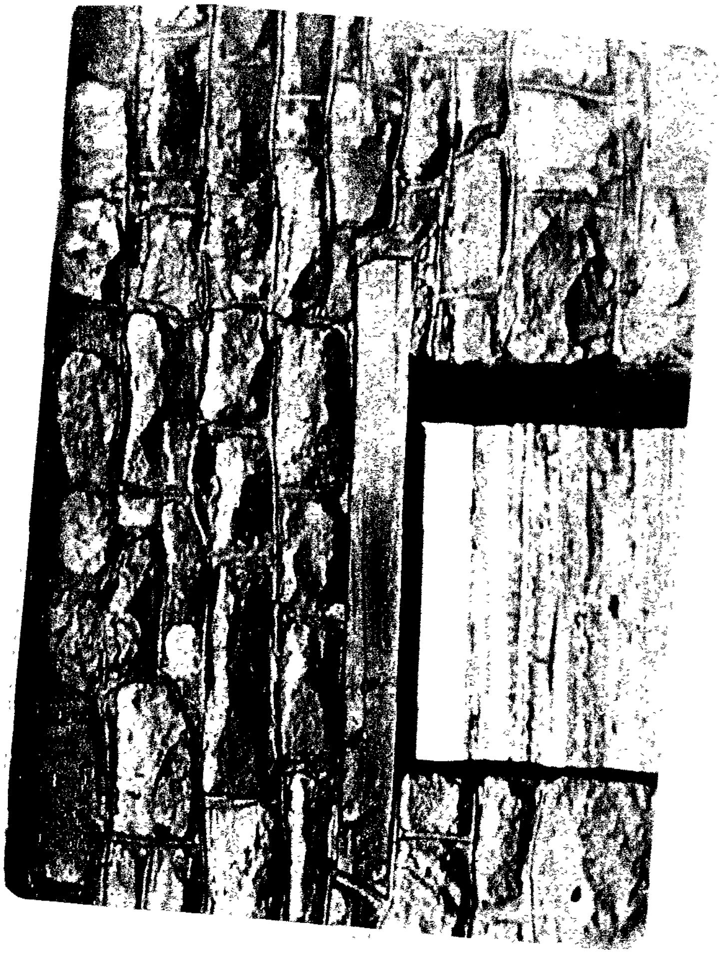
PHOTOGRAPHS OF BURNHAM

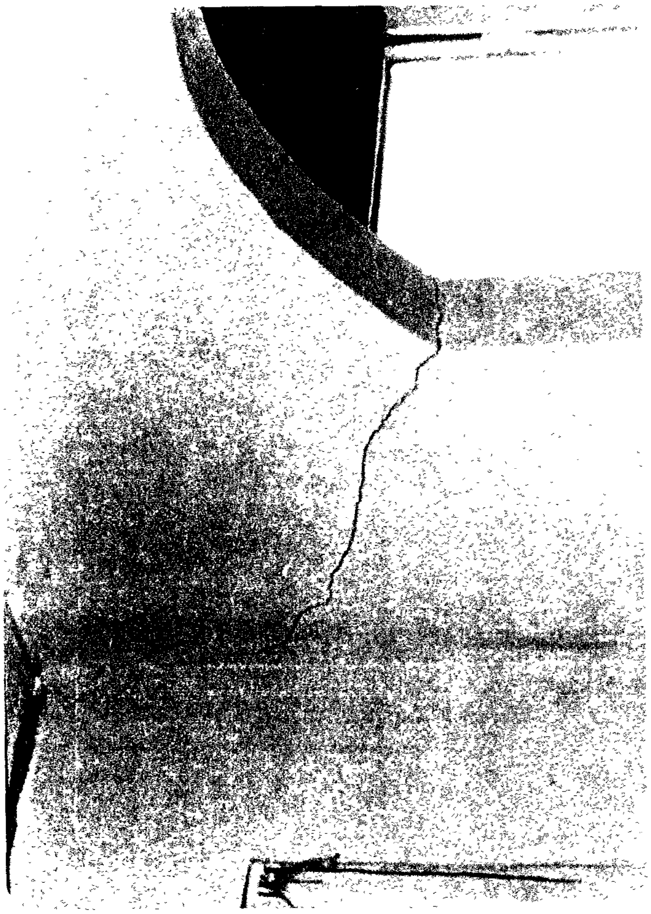
The following twelve photographs show buildings in Burnham, New Mexico. The reader will see the same conditions that have been noted in the preceding photographs in Paguate and other areas.

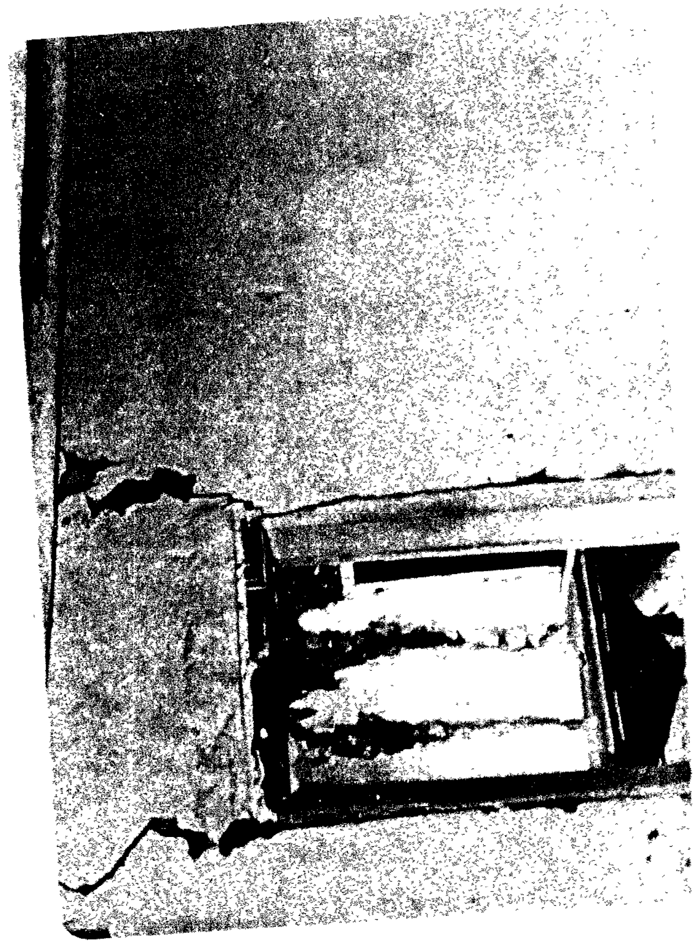
The following photographs were taken to document the conditions of residences in advance of the beginning of blasting operations in that area. Such conditions are common everywhere, but they are often overlooked until brought to the attention of the occupants.











PHOTOGRAPHS OF BLASTING CLOSE TO BUILDINGS

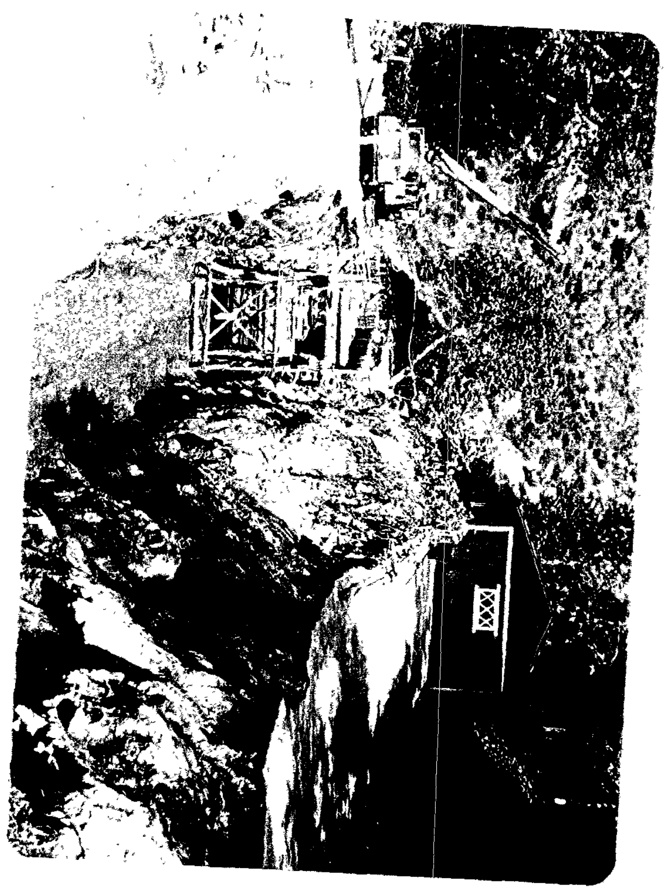
The following ten photographs were selected to illustrate the fact that blasting must often take place very close to existing buildings when construction work must be done in rock regions. The photographs were taken at different times and at different locations.

No damage was done to any of the buildings seen in these photos.

The first photo shows a deep rock cut which was blasted between two of the oldest buildings in California, dating from the Spanish adminstration. One of these was an old adobe structure.

In every case shown here, the vibration intensities greatly exceeded those transmitted to Paguate.



PROFESSIONAL RESUME OF THE AUTHOR

Lewis L. Oriard

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GEOTECHNICAL CONSULTATION
GEOPHYSICS, GEOLOGY
ROCK MECHANICS
EXPLOSIVES ENGINEERING
SHOCK AND VIBRATION

EDUCATION

B.S. in Civil Engineering, Major in Structural Engineering, Gonzaga University.
M.S. in Geophysics and Geology, St. Louis University.
Partial completion, Ph.D., Geophysics, St. Louis University.

AFFILIATIONS

ASCE, ISRM, SME, USCOLD, SSA, SEG, SEE, AEG

REGISTRATIONS (STATE OF CALIFORNIA)

Geophysicst - GP 92.
Geologist - RG 2693.
Engineering Geologist - EG 788.

PROFESSIONAL HISTORY

Lewis L. Oriard, Inc., President, 1977 to date.
Woodward-Clyde Consultants, from Associate to Consulting Principal and Partner,1965-77.
Independent Consultant, 1951-65.
Oriard Powder Co. (explosives), Part Owner and Technical Adviser, 1951-55.
St. Louis University, administrative and teaching faculty, 1947-51.

EXPERIENCE

Mr.Oriard has had some 34 years experience in practical problems in all phases of geotechnical consulting, including engineering geology and geophysics, rock mechanics, explosives engineering, structural dynamics and related questions in the general fields of civil construction, mining and research. He has consulted on approximately 1000 projects in some 30 countries. His experiences include rapid transit systems, tunnels, dams, underground powerhouses, open-pit and underground mining, quarrying operations, nuclear power plants and waste facilities, pipelines, off-shore facilities, highways, canals, other civil works and research projects. Representative assignments include:

Service on Consulting Boards or Review Boards.
Feasibility or pre-bid studies, evaluation of specific site conditions.
Construction problems, methods, technical assistance during construction.
Blasting technology, development of special techniques, evaluation of hazards, dynamic effects on slopes underground openings, civil structures, materials, people and human activity.
Study of physical properties of materials (field and laboratory).
Geological and geophysical exploration.
Rock mechanics: stability of chambers, tunnels, shafts, openings and slopes; reinforcement or support, stabilization and construction techniques.
Instrumentation.
Noise and Vibration.
Tunnel Boring Technology.
Consultation regarding contracts and specifications.

Mr. Oriard has been an invited lecturer at many universities and conferences, both domestic and foreign, and is the author of many technical papers and lectures in his fields of specialization.

TECHNICAL ARTICLES PREPARED BY L. L. ORIARD

"Magnetic and Electrical Exploration Methods in Engineering and Hydrology," presented to American Geophysical Union, University of Idaho, 1960.

"Utilization of Dispersion Effects to Control Explosion-Generated Ground Vibrations," American Geophysical Union, Washington State University, 1963.

"Design Techniques for the Control of Blasting Effects," prepared for Woodward-Clyde & Associates, 1967.

"A Seismic Method of Evaluating the Apparent Refusal of Driven Piles," prepared for Woodward-Clyde & Associates, 1969.

"Geophysical Exploration Methods," Invited Cooperating Scientist, Crustal Movement Monitoring, Technical Report No. 26, The Coordinating Committee for East Bay Fault Slippage, Hayward, California, November, 1969.

"Dynamic Effects on Rock Masses from Blasting Operations," Slope Stability Seminar, University of Nevada, May, 1970.

"Blasting Operations in the Urban Environment," Association of Engineering Geologists Annual Meeting, Washington, D.C., October, 1970. Published in the Bull. AEG, Vol IX, No. 1, Winter, 1972.

"Blasting Effects and Their Control in Open Pit Mining," in "Geotechnical Practice for Stability in Open Pit Mining," Proceedings of the Second International Conference on Stability in Open Pit Mining, Vancouver, B.C., November, 1971, Library of Congress Catalog Card No. 72-86923.

"Specifications for Controlled Blasting in Civil Engineering Projects," co-authored with A. J. Hendron, Jr., Vol 2, Proceedings of the First North American Rapid Excavation and Tunneling Conference, Chicago, Illinois, June, 1972, SME of AIME, Library of Congress Catalog Card No. 72-86918.

"A Guide to Evaluate Damage Potential to Pipelines from Nearby Construction Blasting," a manual prepared for Alyeska Pipeline Service Co., 1972.

"Urban Blasting," First Annual Conference of the Kentucky Division of Explosives and Blasting, Lexington, Kentucky, June 1, 1973.

"Earthquake Source and Effect Concepts Related to Long-Range Planning of U.S. Government Facilities Throughout the World," Seminar for representatives from State Dep't., Bureau of Reclamation, U.S. Geological Survey, U.S. Air Force, Bureau of Standards, Corps of Engineers and World Bank, October, 1973.

"Geotechnical Feasibility of Underground Reactor Siting," co-authored with H. M. Ewoldsen, ASCE Water Resources Conference, Los Angeles, January, 1974.

"Blasting Techniques ad Safeguards Used in Enlarging the Underground Powerhouse at Salto de Villarino, Spain, co-authored with H. M. Ewoldsen and J. Y. Perez, prepared for the Rapid Excavation and Tunneling Conference, San Francisco, SME of AIME, June, 1974.

"Controlled Blasting," prepared for Workshop on Tunnel Blasting, jointly presented by Underground Construction Research Council, Society of Mining Engineers and the University of Maryland, November, 1974.

"Vibration Control," prepared for Workshop on Tunnel Blasting jointly presented by Underground Construction Research Council, Society of Mining Engineers, and the University of Maryland, November, 1974.

"Geophysical Exploration for Deep Underground Structures," co-authored with R. J. Bielefeld, prepared for the 17th Annual Meeting, AEG, Denver, 1974.

"Design Considerations and Stress Analysis for Multiple Underground Openings in Anisotropic Rock, co-authored with B. C. Yen and J. N. Mathur, Society of Mining Engineers Annual Meeting, Tucson, Arizona, 1975.

"Rapid Dam Construction Using the Directed Blasting Method," co-authored with H. M. Ewoldsen and A. Mahmood, prepared for the Second Iranian Congress of Civil Engineering, Pahlavi University, Shiraz, Iran, May, 1976.

"Physical Properties and Geologic Structures of Rock Which Determine its Failure Characteristics Under the Action of High Explosives," presented as Visiting Professor to the National University of Mexico, Mexico City, first offered in July, 1976, and repeated.

"Explosion-Induced Waves in Water, Air, Soil, and Rock, and the Response of Structures and People to These Blasting Effects," presented as Visiting Professor to the National University of Mexico, Mexico City, first offered in July, 1976, then repeated.

"Urban Blasting: Problems and Techniques," prepared for Rock Excavation Seminar, American Society of Civil Engineers, New York, October, 1976.

"A Critical Review of Certain Criteria Used in Explosives Engineering," presented at the American Society of Civil Engineers Geotechnical Specialty Conference on Soil Dynamics and Earthquake Engineering, Pasadena, June, 1978.

"Using Explosives to Excavate Frozen Ground," co-authored with R. G. Tart, prepared for presentation ot the joint United States - U.S.S.R. Seminar on Building in Cold Climates and Permafrost, Leningrad, Russia, 1978.

"Controlled Trench Blasting in Frozen Ground," co-authored with R. G. Tart, prepared for the State-of-the-art Conference on Pipelines in Adverse Environments, American Society of Civil Engineers, New Orleans, January, 1979.

"The Atlanta Research Chamber", contributing author to Monographs on the State-of-the-Art of Tunneling, prepared for the U.S. Dept. of Transportation, Office of Technology and Development and Deployment, June, 1979.

"The Effect of Rock Mass Discontinuities on Machine Tunneling: Buckskin Mountains Tunnel, Arizona, co-authored with S. T. Freeman, presented to the Association of Engineering Geologists, Los Angeles, August, 1979.

"Short-Delay Blasting at Anaconda's Berkeley Open-Pit Mine, Montana", co-authored with Merle Emmert, SME of AIME, February, 1980, AIME Preprint No. 80-60.

"Response of Deep Rock Masses to Vibrations Induced by Nearfield Earthquakes, Blasting or Rock Burst Phenomena", Seismic Design Workshop for Underground Repository, Office of Nuclear Waste Isolation, Department of Energy, Rockwell International, Seattle, 1980.

"Observations on the Performance of Concrete at High Stress Levels From Blasting", Sixth Annual Conference on Explosives and Blasting Technique, Tampa, February, 1980.

Short Course prepared for U.S. Forest Service, presented at Montana State University, March, 1980. Oriard lectures:(related to quarrying and aggregates): (1)Review of Geologic Considerations in Source Location, (2) Origin, Landforms and Characteristics of Unconsolidated Deposits, (3) Geophysical Exploration Methods, (4) Quarry Blasting and Blasting Patterns.

"Short Course in Explosives Engineering", as 2-day extension of the above, offered to the general public, Montana State University, March, 1980.

"Rockfill Quarry Experience, Ord River, Australia", co-authored with Joseph L. Jordan, Journal of the Construction Division of ASCE, March, 1980.

"TVA's Criteria for Blasting Effects on Concrete", co-authored with J. H. Coulson, ASCE National Meeting, Specialty Conference on Minimizing Detrimental Construction Vibrations, Portland, Oregon, April, 1980.

"Blast Damage Criteria for a Massive Concrete Structure", co-authored with R.G.Tart and J. H. Plump, ASCE National Meeting, Specialty Conference on Minimizing Detrimental

Construction Vibrations, Portland, Oregon, April, 1980.

"Seminar in Explosives Engineering", presented to Colegio de Ingenieros Civiles de Mexico, Seccion Monterrey, A. C., presented at Monterrey, Mexico, April 15, 1980.

"Underground Vibrations From Surface Blasting at Jenny Mine, Kentucky", co-authored with D. E. Jensen, R. D. Munson and others, prepared for U.S. Bureau of Mines, Contract No. J0275030, Criteria for Proximity of Surface Blasting to Underground Mines.

"Drilling, Blasting and Dredging Techniques for Deepening the Panama Canal", World Dredging & Marine Construction, Vol 16, No. 6, June, 1980.

"Time Correlations Between Building Cracks and Blasting", Seventh Conference on Explosives and Blasting Technique, Phoenix, Arizona, January, 1981.

"Field Tests With Fracture Control Blasting Techniques", Rapid Excavation and Tunneling Conference, San Francisco, May, 1981.

"Influence of Blasting on Slope Stability; State-of-the-Art", Invited State-of-the-Art paper prepared for the Third International Conference on Stability in Surface Mining, Vancouver, B.C., Canada, June, 1981

"Blasting Effects and Their Control", Underground Mining Methods Handbook prepared by Society of Mining Engineers of AIME, 1982.

LEWIS L. ORIARD

QUALIFICATIONS RELATIVE TO OPEN-PIT MINING AND QUARRYING

Mr. Oriard has consulted on an estimated 150-200 quarries and open-pit mines. Representative samples follow:

TURIMIQUIRI PROJECT, VENEZUELA.
Member of consulting board for the Owner, Instituto Nacional Obras Sanitarias, on a project for two rockfill dams, a 13-mile tunnel, large quarry, undersea pipeline and associated appurtenances. Among other assignments, evaluated the Owner's geological data, recommended the quarry site and its method of development.

BILBAO SUPERPORT, SPAIN.
Selected by the largest construction firm in Spain to provide complete details of quarrying operations to build a mile-long dike into the Atlantic Ocean along the north coast of Spain. Tasks included engineering geological evaluation of the potential quarry site, including suitability and durability of the rock, its fragmentation characteristics, geologic structure and slope stability during development of a quarry face 700 ft. high. Provided details of the mtehod of development of the quarry, size and sequence of excavation lifts, recommendations on all equipment used and design of all details of the blasting methods.

ORD RIVER PROJECT, AUSTRALIA.
Geotechnical consultant to the general contractor. Assignments included many questions related to development of a large quarry in hard quartzite, physical and geological properties of the rock, coyote blasting methods for the largest chemical explosion ever detonated in Australia, the seismic effects of the explosion on freshly grouted dam foundation, concrete, nearby faults and other features.

PALABORA MINE, NORTHEAST TRANSVAAL, AFRICA.
One of the world's largest open-pit mining operations (400,000 tons per day). Accepted the assignment to re-design the blasting methods to solve fragmentation and flyrock problems within rigid economic constraints.

ROSSING MINE, NAMIBIA, AFRICA.
Accepted the assignment to design blasting methods for best fragmentation, highest rate of production and least vibration (mining work was going on simultaneously underground, as well as in the open pit).

CHIVOR PROJECT, COLOMBIA, SOUTH AMERICA.
Selected and evaluated the quarry site for one of the world's highest embankment dams, and provided consultation on other questions related to rock excavation and slope stability.

FUNCHO DAM, PORTUGAL.
Feasibility study for a true ejecta dam. Was selected to present the state-of-the-art in the United States in explosives excavation technology, for comparison to similar presentations from Russia, Sweden and West Germany. This was presented along with a feasibility evaluation of the Funcho site to assess the potential for casting rock ejecta from the abutments across the valley for construction of a dam by explosive excavation.

CABRAS QUARRY, GUAM
Designed the blasting methods to produce large quarry stones (10 tons to 30 tons) needed to repair the U. S. Navy breakwater at Glass Harbor, Guam. Also evaluated the quarry reserves and outlined additional quarry expansion.

ST. THOMAS AIRPORT, VIRGIN ISLANDS.

Was selected as principal consultant for the engineering geological and geophysical work to evaluate and select the quarries needed to build a runway extending into the sea in water up to 90 ft. deep. Consultation involved rock types, physical and mechanical characteristics, methods of quarry development, blasting methods and control of blasting effects. Author of portions of the specifications dealing with the quarrying and building of the dike, drilling and blasting techniques, rock dimensions, blasting limits, etc. On-going consultation during construction.

CONCRETOS MONTERREY, S. A., MONTERREY, MEXICO.

Complete design of methods of development of the quarry, utilizing the Owner's existing equipment. Provided complete design of blasting methods, utilizing state-of-the-art methods for control of blast effects in an urban setting.

ASOCIACION DE PROCESADORES DE ROCAS DE MONTERREY, S. A., MEXICO.

Consultant to an association of 16 quarry operations in the matter of state-of-the-art blasting technology and control of blasting effects in a highly populated area.

VISITING PROFESSOR TO THE NATIONAL UNIVERSITY OF MEXICO.

Short course in rock blasting, including sections on quarry development, drilling and blasting methods, blasting technology and control of blasting effects.

MONTANA STATE UNIVERSITY, BOZEMAN, MONTANA.

Assisted MSU faculty in preparation and presentation of a short course for the U. S. Forest Service on the subject of quarries and aggregates. Oriard lectured on the following topics:

- Review of Geologic Considerations in Source Location.
- Origin, Landforms, and Characteristics of Unconsolidated Deposits.
- Geophysical Methods.
- Quarry Blasting and Blasting Plans.
- Separate 2-day course on blasting technology and blasting effects.

STATE OF WASHINGTON

Conducted geological and geophysical studies for the State of Washington, and located several quarries for their use in Eastern Washington.

WHITMAN COUNTY ENGINEERING DEPARTMENT, WASHINGTON.

Conducted engineering geological and geophysical investigations for over 50 quarries, and provided over-all evaluation to the Owner.

DWORSHAK DAM, IDAHO.

Involved the largest construction contract ever awarded by the U. S. Army Corps of Engineers. Served as consultant to five different construction firms or joint ventures on various aspects of different contracts extending over many years, ranging from geophysical exploration to geology, slope stability, blasting and rock mechanics. One assignment included consultation regarding all aspects of the large-scale quarrying operations (some 6 million cubic yards of excavation), a quarry face in excess of 500 ft. in height, underground chamber to house crushing equipment, access and discharge tunnels, slope stability, blasting methods, vibration controls, seismic instrumentation, criteria for underground shock effects (only a thin shell finally remained over the underground chamber) and other related questions.

Similar projects in many other states and countries.

EXPERIENCE WITH OPEN-PIT MINES AND QUARRIES

Experience covers every size range from small, special-purpose operations to very large-scale operations (400,000 tons per day), all types of product needs, from manufactured sand to 30-ton blocks, every type of geologic material from shale to hard quartzite.

Tasks performed (representative examples):

1. Site selection, including geological and geophysical exploration.
2. Testing and evaluation of physical properties of materials, including strength, durability, in-situ moduli, jointing, structure, petrographic and lithologic studies, particle size, hardness, drillability and other physical properties.
3. Development techniques, benching orientations and dimensions, mining methods, operations sequence, loading, hauling, handling methods, sequences and equipment.
4. Complete design of all aspects of blasting technology, including drilling and blasting designs, product selection, delay patterns and quality control.
5. Complete design and control of all phases of ground vibration and airblast overpressures, environmental evaluations, predictions of blast effects, special designs for control, application of many types of instrumentation, from single-component to 65-channel systems.
6. Consultation on noise and vibration related to blasting operations, and/or equipment and vehicle operation.
7. Slope design, slope stability analysis and control, blasting effects.

Representative projects:

Foreign examples:

Palabora (Transvaal)
Possing (Namibia)
Franco-Belga (Spain)
Funcho (Portugal)
Esmeralda (Colombia)
Ord (Australia)
Guri (Venezuela)
Elco (British Columbia)
Mactaquac (New Brunswick)
Hong Kong
Asbestos (Quebec)
Cabras (Guam)
St. Thomas (Virgin Islands)
Turimiquiri (Venezuela)
Concretos Monterrey (Mexico)
Asociacion de Procesadores (Mexico)
Materiales Triturados (Mexico)
Bilbao (Spain)
Kosrae (Micronesia)

Domestic examples:

Molycorp, Questa, N. M.
Union Carbide, Uravan, CO
Anaconda, Butte, Montana
Anaconda, Yerington, Nevada
Anaconda, Bluewater, N. M.
Westmoreland, Hardin, Montana
Kiewit (Big Horn Coal), Sheridan, Wyo.
Amax (Eagle Butte), Gillette, Wyoming.
Amax (Belle Ayre), Gillette, Wyoming.
Utah International, Alton, Utah.
Weyerhauser, Portland, Oregon.
3M Company, Corona, California.

Other examples in Washington, Oregon, California, Idaho, Montana, Wyoming, Colorado, Utah, Alaska, Missouri, Kansas, New Jersey, Ohio, Illinois, etc.

Miscellaneous teaching, research, seminars, lectures:

Foreign examples:
Mexico, Canada, Venezuela, Panama, Portugal, South Africa, Namibia, Colombia, (some associated with projects, some strictly instructional).

Domestic examples:
U. S. Bureau of Mines, U.S. Forest Service, WAshington Dep't. of Highways, American Society of Civil Engineers, Society of Mining Engineers, Private Consulting Firms (Geotechnical, Civil, Mining), Universities.

LEWIS L. ORIARD QUALIFICATIONS (CONT'D)

EXPERIENCE WITH FEDERAL AGENCIES

Have provide consultation for the following U.S. Federal Agencies:

- U. S. Navy
- U. S. Air Force
- U. S. Department of Defense
- U. S. Atomic Energy Commission
- U. S. Office of Nuclear Waste Isolation
- U. S. Department of Transportation
- U. S. Army Corps of Engineers
- The Panama Canal Company
- Explosives Excavation Research Laboratories
- Tennessee Valley Authority
- U. S. Department of Energy
- U. S. Department of the Interior
- U. S. Bureau of Mines
- U. S. Bureau of Reclamation
- U. S. Bureau of Indian Affairs
- U. S. Department of Health
- U. S. State Department
- Agency for International Development
- World Bank
- National Bureau of Standards
- Urban Mass Transit Authority
- Office of Pipeline Safety,
  Office of the Federal Inspector.